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CALCAREOUS GREEN ALGAE FROM THE UPPER CRETACEOUS OF TRIPOLI (NORTH AFRICA)

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ABSTRACT

The flora described by Miss Rita Raineri in 1922 is revised on the basis of the original material. Seven species are discussed, of which two are considered new and one is rejected as an echinoid radiole.

It is well known to students of fossil algae that investigation of these forms is seriously hindered by insufficient knowledge of one of the richest and most important floras, that of the Upper Cretaceous of North Africa. This flora was described more than ten years ago by Miss Rita Raineri (1922). She was kind enough to lend me for examination her slides, from which I made notes and drawings, but I did not publish my results, except for short references in various papers (Pia, 1925; Hirmer, 1927; Pia, Pfender, and Termier, 1932; Rama Rao and Pia, 1935). The present paper is a redescription of Miss Raineri's material, based entirely on her slides.

The age of the flora seems not accurately known. It is Cenomanian or Turonian. Heinz (1934, p. 721) recently proposed the term "Lüneburgian" as a comprehensive name for the Cenomanian and Turonian strata. It is adopted as useful in the present instance.

The localities from which the specimens were collected are in the Italian colony of Libya, not far from the city of Tripoli.

THE FLORA

Most of the algae are comparatively small and not well preserved. I was able to distinguish the following species:

Dissocladella undulata (Raineri), a primitive small species without clear adaptation of the primary branches to their function as sporangia.

Trinocladus tripolitanus Raineri, an interesting transitional type between the genera *Dissocladella* and *Thyrsoporella*.

Neomeris, at least two species, in poor preservation.

Acicularia antiqua Pia, n. sp., the oldest and most primitive representative of the genus, showing a certain resemblance to *Terquemella*.

Boueina pygmaea Pia, n. sp., distinguished from *B. hochstetteri* by its smaller size.

"*Actinoporella cretacica* Raineri," an echinoid radiole.

I am not dealing here with the Corallinaceae of the Libyan Cretaceous limestones, which were described by Raineri in a separate paper (1920).

The flora of the Lüneburgian of Libya resembles that of the Danian of South India (Rama Rao and Pia, 1935) in the frequent occurrence of *Dissocladella* and *Acicularia*. It differs in the presence of *Neomeris* and

Boueina as well as in the absence of *Indopolia* and *Orioporella*.

In Morocco a small flora was discovered a few years ago, the age of which was fixed as Danian. In my opinion it is perhaps Paleocene (Pia, Pfender, and Termier, 1932). It contains *Neomeris*, numerous *Acicularia* more highly specialized than the Libyan and Indian forms, and *Halimeda* instead of *Boueina*.

Many of the differences in these floras are certainly accidental. Much more work will be needed before the Cretaceous Dasycladaceae can be used for stratigraphic correlation in the same way as the Triassic species are used, but I trust that this will be possible at some future date.

Acknowledgments.—I take this opportunity of thanking Miss Raineri again for her kindness and magnanimity. I also wish to thank Professor Erling Dorf for his help in the preparation of my manuscript.

The manuscript was received by the editor of the Journal May 2, 1935.

SYSTEMATIC DESCRIPTIONS

In the following descriptions these abbreviations are used: D, diameter of skeleton. d, diameter of axial cavity. p_1, maximum diameter of primary pores. p_2, maximum diameter of secondary pores. l_1, length of primary pores. In "*Actinoporella cretacica*": d', outer diameter of the central tube. n, number of radial plates.

Measurements in millimeters of Dissocladella undulata (*Raineri*) *var.*

D	d	= D%	p_1	p_2
0.24	0.08	33	——	——
0.25	0.09	34	0.04	0.056
0.25	0.10	37	0.04	——
0.28	0.09	31	——	——
0.29	0.10	32	0.032	0.024
0.29	0.10	33	——	——
0.29	0.10	36	0.056	0.032
0.32	0.10	33	0.049	0.056

DISSOCLADELLA UNDULATA (Raineri) var.

Plate 1, figures 1–12

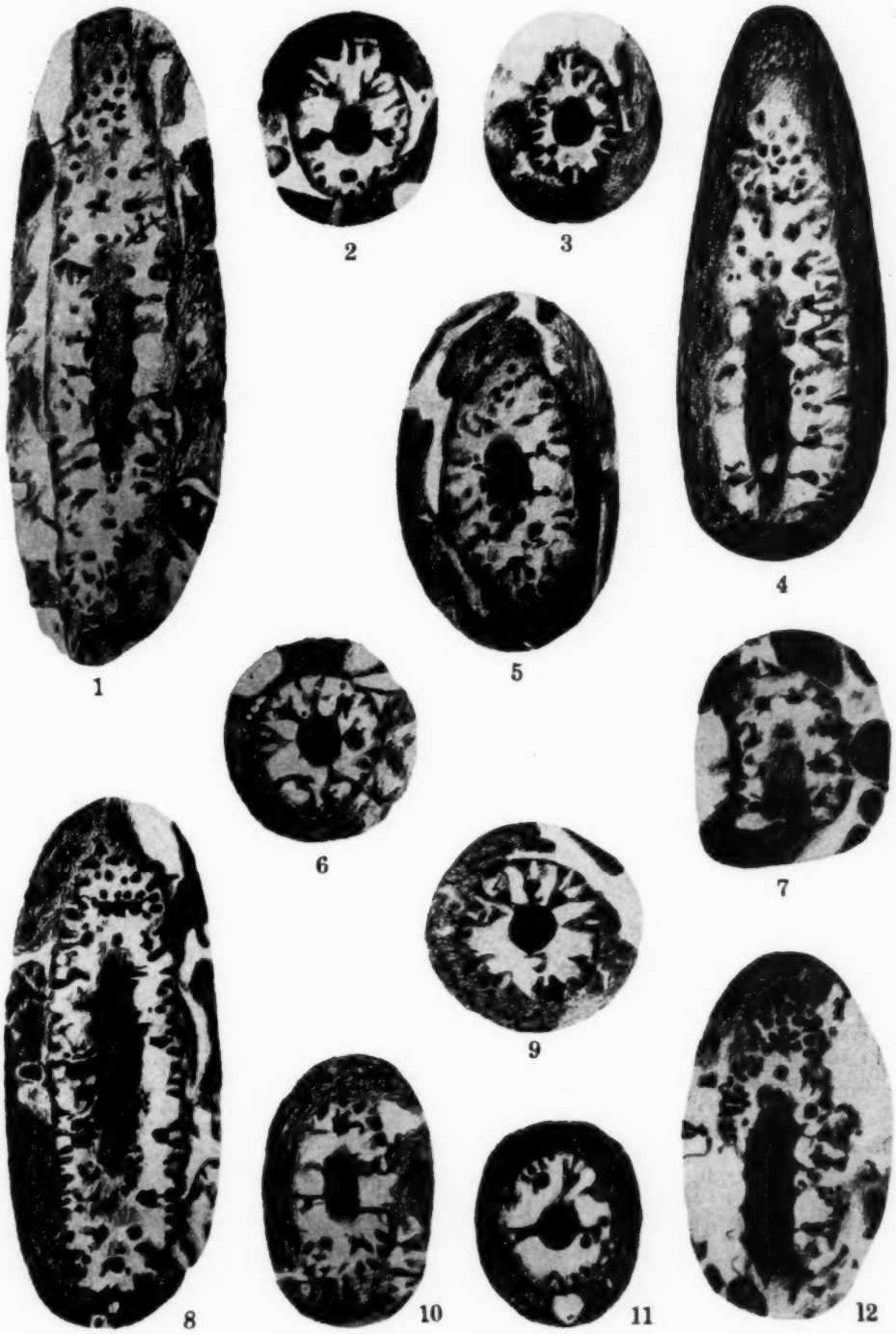
Neomeris cretacea var. *undulata* RAINERI, *1922*, p. 74.
Trinocladus undulatus (Raineri), PIA in Hirmer, *1927*, p. 77.
Dissocladella undulata (Raineri), RAMA RAO and PIA, *1935*.

Thallus cylindrical. Greatest length of the calcareous incrustation measured in a slide 1.4 mm. This is, of course, only a lower limit for the real length, as the section was not strictly longitudinal. Other measurements are shown in the table.

The relative width of the axial cavity, as expressed in percentage, varies very slightly, which seems to indicate that the incrustation was in direct contact with the axial cell, for it is to be assumed that the central cavity would show greater variability if its width were controlled only by the deposition of more or less calcium carbonate on the inner surface of the skeleton. This supposition is strengthened by the very regular, smooth inner surface of the skeleton, which can best be explained as being modeled directly by the axial cell. In cross sections the axial cavity appears circular (Pl. 1, figs. 3, 6, 9); in longitudinal sections (Pl. 1, figs. 1, 4) it is broadly constricted between the whorls of branches, which originate upon rather sharply defined swellings of the axial cell. The name given to the species by Miss Raineri was derived from this character. The shape of

EXPLANATION OF PLATE 1

FIGS. *1–12*—Sections through the skeleton of *Dissocladella undulata* (Raineri) var., ×60, from the Upper Cretaceous of Teghrenna (Garian), near Tripoli, Libya, North Africa. *2*, *11* from Miss Raineri's slide 5; *8* from slide 16; *1*, *9* from slide 17; *6*, *10* from slide 18; other figures from slide 21. Drawings by the author. (p. 4)



Pia, Cretaceous Algae

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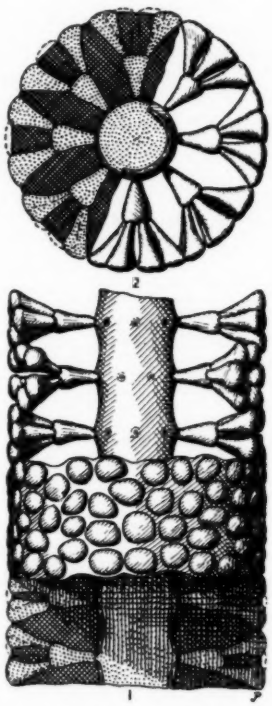
the axial cell deduced from the axial cavity very much resembles that in *Triploporella fraasi* (Steinmann, 1899, p. 138).

There are about eight primary pores in a whorl (Pl. 1, figs. 6, 9), narrow where they open into the axial cavity and expanding outward. Their diameter (not to be measured very exactly) is 11 to 19 per cent of the total thickness of skeleton. About six secondary pores originate from the distal end of a primary pore (Pl. 1, figs. 4, 8, 12), resembling the primary pores in shape and dimensions. On the surface of the skeleton their broad distal ends are closely crowded together. The living plant seems to have been covered by a sort of cortical layer (Pl. 1, figs. 3, 12). No trace of tertiary pores could be discovered in this species.



FIGS. *1, 2*—*Disocladella undulata* Raineri var. ×120. *1*, Reconstruction of part of the thallus. In the upper third of the figure the calcareous skeleton and part of the branches are removed. The middle zone shows the appearance of the complete alga. The lower part of the figure gives a diagrammatic longitudinal section through the soft body and the skeleton. The protoplasm is marked by dots, the calcareous skeleton by cross-hatching. *2*, Reconstruction of whorl seen from above.

As shown by Raineri's description and figures, as well as by the labels on the slides, at least the majority of her specimens of *Neomeris cretacea undulata* belong to the species under consideration. I am fairly certain that her figures 8, 9, 10 and 11 represent this species; figure 5 might be a *Boueina;* I am not able to name figures 6 and 7; the latter is possibly some other fossil, not an alga.

The genus *Dissocladella* has been discussed in more detail elsewhere (Rama Rao and Pia, 1935). The species under examination does not show separate sporangia, and the spores were probably produced in the primary branches. There were many more than two secondary twigs attached to a branch. I can therefore not agree with Miss Raineri concerning the generic position of her species.

Localities: Teghrenna (Garian) and police-barracks of Msellata-Homs.

TRINOCLADUS TRIPOLITANUS Raineri

Plate 2, figures 1–10

Trinocladus tripolitanus RAINERI, *1922*, p. 79, pl. 3, figs. 15, 16.

According to Raineri the greatest length of a section of this species is 3.36 mm. I thought it superfluous to search the slides for a still longer specimen, for the real length of the thallus was probably much greater. I am under the impression that it was of a rather slender, cylindrical shape. Measurements are as follows:

1. Specimen in which only the primary branches were encompassed by the calcareous skeleton:

$D = 0.47$ mm. $d = 0.16$ mm. $= 34\%$ of D.

2. Specimen with primary and secondary pores:

$D = 0.61$ mm. $d = 0.14$ mm. $= 23\%$ of D.

3. Specimen with tertiary pores clearly visible:

D=0.68 mm. d=0.19 mm.=28% of D.
l_1=0.135 mm.=20% of D.
p_1=0.087 mm.=13% of D.

The arrangement of the primary pores in whorls in easily recognisable in the slides. The branches in successive whorls generally do not alternate; on the contrary, they show a tendency to form longitudinal rows (Pl. 2, fig. 8). In a specimen 2.2 mm. long I counted 20 whorls, in another of the same length 21. The distance of the whorls (from center to center) is therefore a little more than 0.1 mm. The primary pores are filled with a very dark sedimentary material, which probably owes its color to carbonaceous matter derived from the soft body of the alga. The branches were approximately club-shaped and rather thick. Generally a cluster of secondary pores arises from the external end of a primary pore. In some specimens, however, the stout primary pores open directly on the surface of the skeleton (Pl. 2, figs. 2, 5). Sections like that shown in Pl. 2, fig. 4, prove that these specimens belong to *Trinocladus tripolitanus*. They show the ramification of some branches, while others obviously divided into secondary twigs beyond the calcareous incrustation. I was not able to determine exactly the number of secondary pores belonging to a primary pore. Sections like Pl. 2, figs. 1, 3, and 9, indicate that the clusters contained at least 5 or 6 pores.

The secondary pores repeat on a smaller scale the shape of the primary pores, narrow at their bases, expanding outward, and generally opening on the outer surface. Some, however, divide again immediately below this surface, giving rise to tertiary pores, an important fact already recognised by Miss Raineri. The tertiary pores are short and slender (Pl. 2, figs. 6, 10), and about six of them formed a cluster. About 30 tertiary twigs were attached to a primary branch and about 250 to a whorl. Miss Raineri gives a much smaller figure, about 60, but she seems to have overlooked the fact that a longitudinal section of a branch never shows the full number of the twigs attached to it. This can only be seen in a cross-section of the basal part of a cluster.

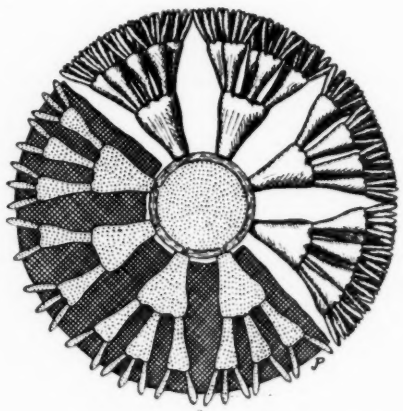


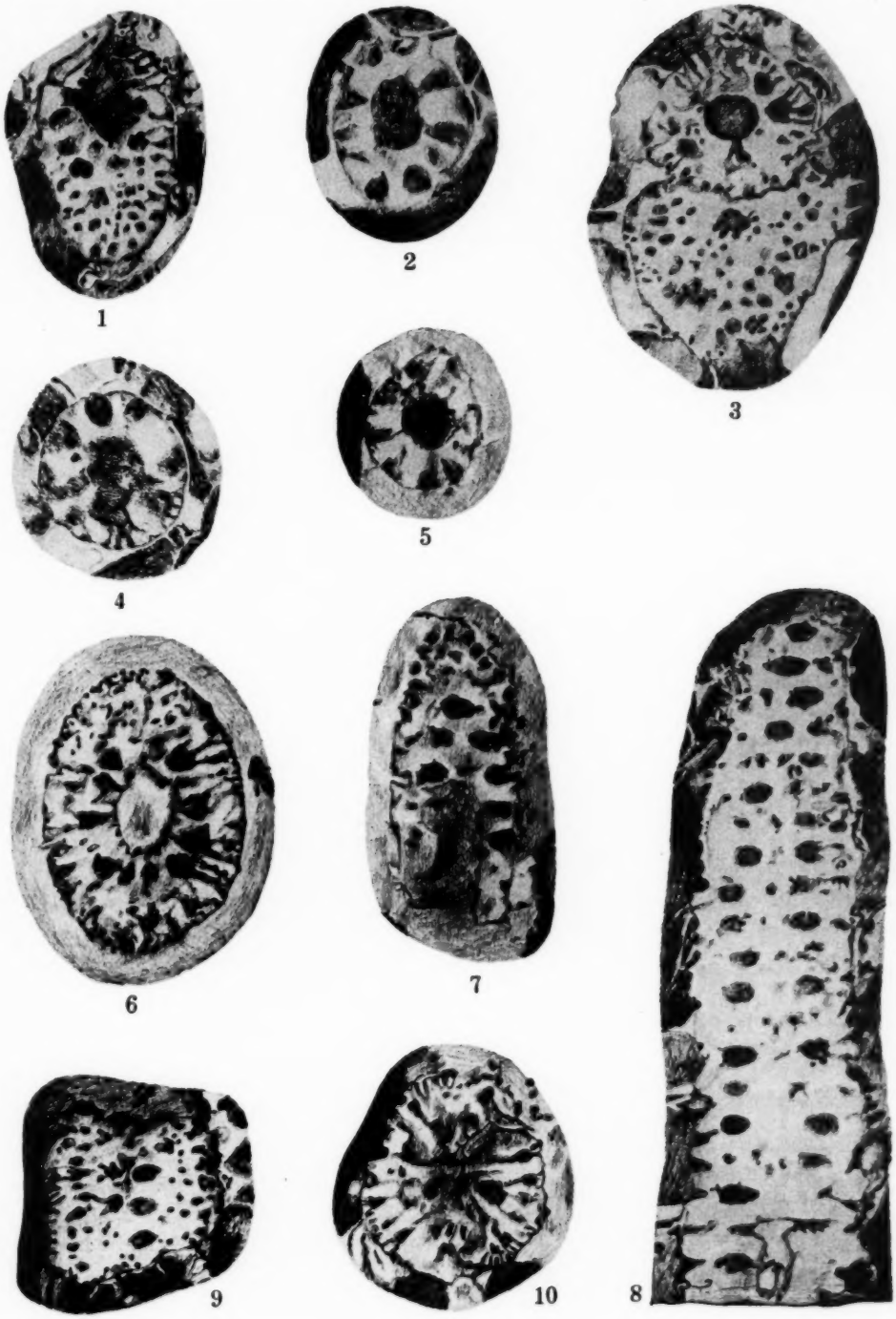
FIG. 3—*Trinocladus tripolitanus* Raineri. Reconstruction of a whorl with tertiary twigs, seen from above, ×80. The protoplasm is marked by dots, the calcareous skeleton by cross-hatching.

Raineri explains the frequent occurrence of sections lacking tertiary, or even secondary, pores as an effect of mechanical erosion, the removal of the outer part of the skeleton, which may have been less compact from the beginning. Under this assumption specimens showing primary pores only ought to agree fully with the inner part of specimens that

EXPLANATION OF PLATE 2

FIGS. *1–10*—Sections through the skeleton of *Trinocladus tripolitanus* Raineri, ×42, from the Upper Cretaceous of the Wadi Msaaba, near Tripoli, Libya, North Africa. *2* from Miss Raineri's slide 7; *5–7* from slide 9; other figures from slide 12. *2*, *5*, specimens with primary pores only; in *4* two main pores bear secondary ones; *6*, *10*, specimens with tertiary pores; *10* probably a section near the apex of the plant; *3*, two fragments of different orientation closely packed together. Drawings by the author.

(p. 5)



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show a richer development of pores. I tried to test this hypothesis by a series of measurements. Under (*a*) are given below the diameters of specimens without secondary pores; under (*b*) the distances between the distal ends of opposed primary pores of specimens showing branching.

(*a*). 0.47 mm., 0.50 mm., average, 0.48 mm.

(*b*). 0.35 mm., 0.44 mm., 0.47 mm., 0.48 mm., 0.36 mm., 0.34 mm.; average, 0.41 mm.

Considering the small number of specimens the difference between the two series of measurements is of little real value. In any case, however, we have to keep another possibility in mind—that some whorls never had secondary and tertiary twigs. Probably this was not a peculiarity of certain plants, but of certain parts, presumably the lower ones, of each plant. Sections showing this simple type are not numerous in the slides. Probably the part of the alga with primary twigs only was not of great extension; above it, perhaps, was the part with primary and secondary pores, apparently the major part, as sections of it are common. In the uppermost region of the alga primary, secondary and tertiary branches were encompassed by the calcareous envelope. On a former occasion I gave a similar interpretation of the structure of *Palaeodasycladus* (Pia, 1920, p. 120).

It seems very probable that the primary branches contained uncalcified spores, at least where they bore secondary twigs. The dark color of their contents may be an indication of a former rich accumulation of protoplasm. Sections with primary pores only may correspond to a sterile, lower region of the alga, such as is well known in the Recent *Neomeris*. In the region with tertiary twigs the secondary twigs likwise may have contained spores.

I was not able to fix exactly the shape of the tertiary twigs. They may have formed a cortex, or possibly they bore assimilatory trichomes.

Trinocladus tripolitanus may be distinguished from *Dissocladella undulata* by the following characters: The diameter of the skeleton is decidedly larger. Tertiary pores are occasionally present. The secondary pores are much smaller than the primary ones.

Trinocladus tripolitanus is an excellent transitional type between the genera *Dissocladella* and *Thyrsoporella*.

I consider Raineri's figure 15 to be the type of our species. Figure 16 very probably also belongs to it, though it does not show tertiary twigs.

All the slides containing *Trinocladus tripolitanus* are labelled "Wadi Msaaba" (near Msellata).

Neomeris, several spp.

Plate 3, figures 18–22

As already explained, the algae assigned by Raineri to *Neomeris cretacea* do not belong to that genus. This does not mean however, that the genus *Neomeris* is not represented in the Luneburgian of Tripoli. I think it highly probable that fragments of at least two species are present in the slides. It is not surprising that only fragments rather difficult to determine were found, for the skeleton of *Neomeris* is always rather frail.

A few tangential sections through fragments of skeletons show two kinds of pores, larger pores of a very regular, circular shape, probably sporangia; and smaller pores, often somewhat irregular. The smaller pores seem to be more numerous than the larger pores (Pl. 2, figs. 18, 20). The diameter is about 0.095 mm. and 0.03 to 0.04 mm. respectively. Probably two small pores belong to a large pore, a relation characteristic of the genus *Neomeris*.

My interpretation is confirmed by cross-sections like that shown on Pl. 3, fig. 19, which shows the larger cavities to be spherical (obviously opened on the external side by attrition), whereas the smaller pores pierce the skeleton. The thickness of the calcareous incrustation seems to be about 0.12 mm. in this specimen.

This species differs widely from *Neomeris cretacea* Steinmann. The sporangia are spherical, not pear-shaped, the wall of the skeleton is much thinner, etc. Sections of this character are visible in slides from Teghrenna, Msellata-Homs, and perhaps also from the Wadi Msaaba.

A second, much rarer species probably belonging to *Neomeris* occurs in the rock-specimens from Teghrenna. It is represented by fragmentary cross-sections, no tangential sections referable to it having been observed. Pl. 3, fig. 21 shows a sporangium encircled by two secondary branches. A third twig observable in the same fragment may belong to another primary branch. The fact that the primary branches were not calcified and are, therefore, not preserved is indicative of the genus *Neomeris*. It was not possible to observe the decisive character of this genus, the number of twigs in a cluster. Pl. 3, fig. 22 seems to hint at a more obovate than spherical shape of the sporangium; the size is much larger than in the specimens described above: breadth of the sporangium, 0.14 mm.; thickness of the shell, 0.23 mm. It seems therefore that the second species was larger than *Neomeris cretacea* (Steinmann 1899, p. 150). The calcareous incrustation is thinner than in Steinmann's species.

Until more complete specimens are at our disposal, it does not seem advisable to give specific names to the specimens of *Neomeris* from Tripoli.

ACICULARIA ANTIQUA Pia, n. sp.

Plate 3, figures 1–14

The genus *Acicularia* was not mentioned by Miss Raineri in her paper, but it occurs rather commonly in the slides. The problem of the determination of *Acicularia* in sections has been thoroughly discussed elsewhere (Rama Rao and Pia, 1935), so that I do not need to go into much detail now.

In the slides the spicules of *Acicularia* appear as bright, roundish or somewhat oblong discs with circular, generally very dark, dots along the periphery, corresponding to the sporangial cavities. The central part of the disc as a rule is devoid of sporangia. Sections that show traces of them in the middle part may be supposed to be more or less tangential. In considering the sections represented on Pl. 3 and many others in the slides, I was at once struck by the absence of long, narrow figures, such as would correspond to longitudinal sections of the more familiar spicules of *Acicularia* from the Tertiary. I have shown (Rama Rao and Pia, 1935, p. 45) that this can not be explained by pure chance. My mathematical deductions are confirmed by the empirical fact that in the echinoid radioles to be described below very long sections are fairly common. It is therefore evident that the spicules of the Cretaceous Acicullariae were not needle-shaped, their length probably not exceeding twice the thickness in *A. antiqua*. Small sections

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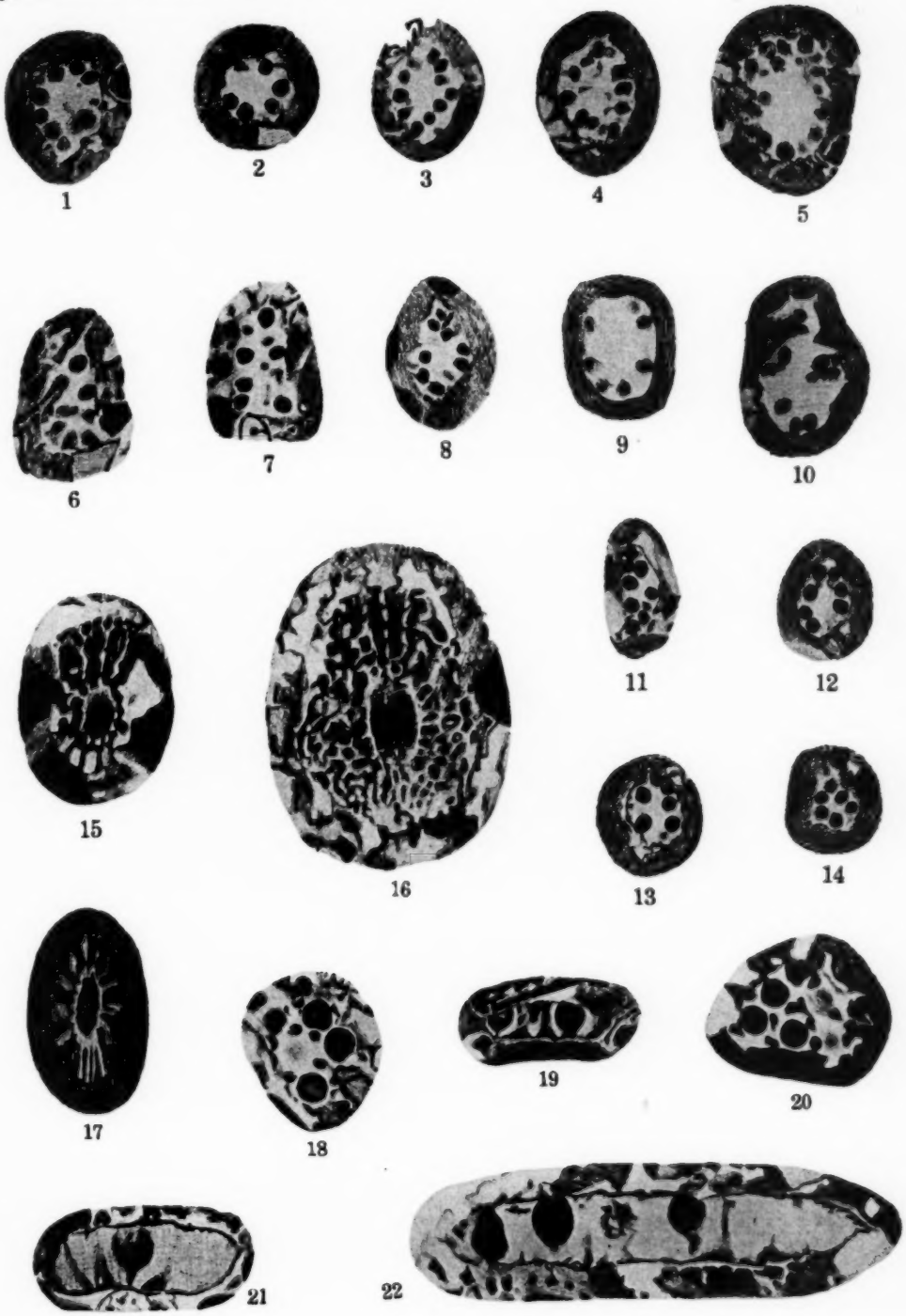
EXPLANATION OF PLATE 3

FIGS. *1–14*—Sections through spicules of *Acicularia antiqua* Pia, n. sp., ×38, from the Upper Cretaceous of Teghrenna (Garian), near Tripoli, Libya, North Africa. *3* from Miss Rainer's slide 5; *6*, *10* from slide 15; *12* from slide 16; *1*, *2*, *4*, *7*, *14* from slide 17; *13* from slide 18; *5*, *8*, *9*, *11* from slide 21. (p. 8)

15–17—Sections through more or less "anomalous" specimens of "*Actinoporella cretacica*" Raineri (radioles of Holasteridae or Spatangidae), ×92, from the Upper Cretaceous of Teghrenna. *15* from Miss Raineri's slide 4; *16* from slide 18; *17* from slide **5.** (p. 9)

18–22—Sections through fragments of the skeleton of *Neomeris* sp., ×42, from the Upper Cretaceous of Teghrenna. *18*, *20*, tangential sections; *19*, *21*, *22*, cross-sections of the calcareous incrustation. *18*, *20* from Miss Rainer's slide 17; *19* from slide 21; *21* from slide 5; *22* from slide 6. Drawings by the author. (p. 7)



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like that shown in Pl. 3, fig. 14 are most probably cross-sections through the pointed end.

The greatest diameter of spicule observed is about 0.33 mm. The diameter of the spore-cavities varies between 0.04 and 0.055 mm. Theoretically the sections never show the true diameter of the spore-cavities, as the probability of a cavity being cut exactly through its center is very small. Sections not too distant from the center are, however, practically equal to central sections; moreover the thickness of the rock-slices must not be neglected, for this increases the possibility of finding the real diameter. In any case the different specimens show differences in the size of the sporangia that can hardly be explained by casual differences in the direction of the sections. Whether they are of any systematic value is quite another question. In my material from the Danian of South India the Acicularíae could be grouped according to size of the sporangia, but this does not seem possible in the African slides.It may be that the name *Acicularia antiqua* covers more than one species, but I am not able at present to distinguish them.

A. antiqua closely resembles *A. dyumatsenae* from the Niniyur strata (Danian) of South India. The spore-cavities are of about the same size, though the African species is perhaps a little stouter. No hooked sections, such as occur in the Niniyur strata, were observed in the material from Tripoli.

A full description of *A. antiqua* can not be given until it is found in rocks from which it can be isolated by washing. It may be that together with *A. dyumatsenae* it represents a new genus transitional between *Terquemella* and *Acicularia*. I found it only in slides from Teghrenna.

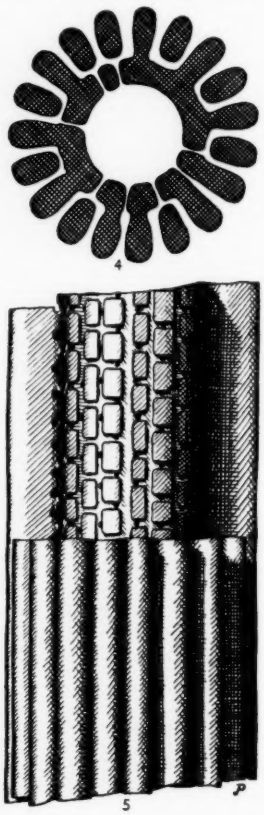
"ACTINOPORELLA CRETACICA" Raineri
Plate 3, figures 15–17; Plate 4, figures 1–16
Actinoporella cretacica RAINERI, *1922*, p. 76, pl. 3, figs. 12–14.

This fossil is very common in the slides. Miss Raineri's description was one of the chief reasons for asking her to lend me her material. In particular her figure 14 seemed to look rather strange for one of the Dasycladacea. By carefully studying the slides and accurately drawing 20 microscopical figures I convinced myself that "*Actinoporella cretacica*" cannot be a calcareous alga. To prove this conviction, it is necessary to give a thorough description of the structure of the fossil —which might also be of some general, methodological interest.

We may start from transverse cross-sections like Raineri's fig. 12 and my Pl. 4, figs. 7–10. The center of the fossil is occupied by a cavity filled with dark rock-material. The skeleton itself consists of white, translucent calcite. It may be described as a star-like figure or as a ring with radial projections. The breadth of the furrows separating the projections varies in different sections—generally they are decidedly narrower than the prominences. Such a section perpendicular to the axis of the fossil gives a very incomplete insight into the structure—a point too often neglected in micropaleontological descriptions, for the general shape of the fossil may just as well be spherical as cylindrical; the radial prominences may be rods or plates. That the prominences in the present specimens are not rods is indicated by a streak of dark limestone separating some of them from the central ring. As they keep their regular position, they must have been connected with the ring above or below the level of the section. The central ring is also often interrupted by delicate dark lines corresponding to pores or fissures.

As in many analogous cases the real structure appears quite clearly in more or less oblique longitudinal sections. It seems that Miss Raineri did not recognise the connection between these long sections and those of star-like form. This connection is, however, clearly shown by the transitional sections, Pl. 4, figs. 1–6, in which the angle between the axis of the fossil and the slide becomes smaller and smaller.

The oblique sections show first of all that the "central ring" is a long tube, perforated by small, roundish pores (see especially figure 2). The pores are arranged alternately in longitudinal rows. They do not seem to be equally well and regularly developed in all the different specimens. The radial projections are plates attached to the tube; if they were rods, they ought to appear in the longitudinal sections as small circular or elliptical dots, not, as they really do, as long, slightly diverging strips. The plates increase slightly in thickness toward the outer margins, which in turn are well rounded. In their adaxial parts, close to the central cylinder, they are pierced by a single row of comparatively wide pores. If one of these pores is visible in a cross-section, it produces the dark streak separating the projection from the central ring, as described above. In a very slightly oblique longitudinal section quite a number of pores are visible (Pl, 4. figs. 1–3).



FIGS. *4, 5*—"*Actinoporella cretacica*" Raineri (a radiole of an holasterid or a spatangid echinoid), ×333. *4*, Diagrammatic cross-section. *5*, Side view of a fragment. In the upper half of the figure the radial plates are partly removed to show the pores.

From these observations we deduce the reconstruction shown in text-figures 4, 5. Briefly recapitulating the above description, the drawing shows first the central tube and the radial plates, then the following cavities: The axial cavity; the radial furrows separating the plates; the tangential pores perforating the plates in their basal part and thus connecting one furrow to the other; the radial pores leading from the axial cavity directly into the furrows or into the tangential pores.

No definite rule as to the position of the pores in neighboring plates could be detected. Sometimes they seem to alternate, sometimes not (Pl. 4, figs. 1–3).

The dimensions of the fossil may be shown in a few examples (see table).

The length of the fossil can not have been much less than 1 mm.; probably it was more. None of the specimens show the original end of the fossil. On the contrary, all the long, oblique sections are limited, at least on one side, by a frac-

EXPLANATION OF PLATE 4

FIGS. *1–16*—Sections through "*Actinoporella cretacica*" Raineri (radioles of Holasteridae or Spatangidae), ×92. *1–10*, "normal specimens"; *11–15*, "anomalous specimens"; from the Upper Cretaceous of Teghrenna (Garian), near Tripoli, Libya, North Africa. *16*, a comparable section from Wadi Msaaba. *3, 10, 12* from Miss Raineri's slide 4; *4, 6–9* from slide 5; *1, 5, 11, 13, 14*, from slide 6; *16* from slide 13; *2* from slide 15; *15* from slide 16. Drawings by the author. (p. 9)

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Pia, Cretaceous Algae

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Measurements in millimeters of "normal" sections of "Actinoporella cretacica" *Raineri*

Spec. no.	Pl. 4, fig.	D	$d' = \%D$		$d = \%D$		n
1	7	0.13	0.075	56	0.043	32	17
2	9	0.13	0.080	60	0.053	40	19
3	5	0.14	0.086	62	0.059	42	19
4	10	0.16	0.102	63	0.064	40	19
5	8	0.17	0.102	61	0.075	45	21
6	4	0.17	0.091	53	0.059	34	18

ture. The radial plates of the specimens recorded in this and the next table are present in an odd number, with but two exceptions. The type of section hitherto considered is the most common one and therefore may be taken as the normal section. Certain other sections are of a different sort, the relation of which to the normal type is discussed below. Among these "anomalous" sections two groups can be distinguished.

Pl. 3, figs. 15 and 16 show specimens in which the radial plates are only faintly discernible; they are mostly replaced by a system of quite irregular calcareous lamellae. Figure 15 is of special interest, for it shows on one side a structure closely approaching the normal one, and proves thereby that both structures belong to different parts of the same body. The section on Pl. 3, fig. 16 is much larger than all the others; for it (specimen 7), D is 0.32 mm., and d is 0.07 mm. or 23 per cent of D. Figure 15 also indicates that the portion with the irregular structure has a greater diameter than the normal one. One may conjecture therefore that the irregular sections correspond to the broader end of the problematical fossil.

The other group of anomalous sections is characterised by small size and by reduction of all the cavities, especially of the axial perforation. In Pl. 4, fig. 13 the axial cavity is represented by two small pores only; in fig. 12 it contains a star-like body of crystalline calcite, which may or may not belong to the fossil. In fig. 11 the radial furrows are transformed into closed canals. Raineri's fig. 14 also may represent this type (compare Pl. 4, fig. 14). Parts of the two long projections shown in Raineri's drawing do not belong to the fossil under consideration, but to another calcareous body of an uncertain nature. Pl. 4, fig. 15 seems to represent an oblique section without any trace of the axial cavity.

The dimensions of these small sections are shown in the next table.

Measurements in millimeters of small, "anomalous" sections of "Actinoporella cretacica" *Raineri*

Spec. no.	Pl. 4, fig.	D	$d' = \%D$		$d = \%D$		n
8	13	0.080	0.024	30	0.0053	7	10
9	14	0.080	0.032	40	0.019	23	9
10	11	0.107	0.032	30	0.013	12	9
11	12	0.107	0.051	48	0.032	30	13

It is not clear whether these anomalous sections of the second group belong to the same individuals as the normal sections. Some transitions are to be seen (Pl. 4, figs. 12, 14, 16). One could surmise that we are here dealing with the tapering, pointed end of the fossil. The more compact structure would agree with this hypothesis, though some difficulty arises from the fact that the number of radial plates is less in the small sections than in the normal sections. It seems, however, possible that new plates were intercalated in the transitional region or that some plates bifurcated.

The majority of the sections upon which my description is based are from Garian (Teghrenna). They are present also in rock from the barracks of Msellata-Homs, and very similar bodies are occasionally found in the rock from Wadi Msaaba (Pl. 4, fig. 16).

We have now to consider the question of the group of organisms to which "*Actinoporella cretacica*" may belong. It is quite obvious from the above description that the fossil is not a member of the Dasycladaceae nor any other calcareous alga. This possibility was excluded as soon as it was made clear that the radial projections are plates, not rods, and that they do not contain radial pores starting from the axial cavity and leading to the outer edges.

In searching the literature for similar

fossils I came across several figures in the beautiful *Album de microphotographies de roches sédimentaires* by Hovelacque. On Pl. 32 there appears near the center of fig. 2 a section comparable to the African fossil; it is called "Organisme indéterminé" in the explanation. A still closer resemblance is shown by some sections in fig. 2 of Pl. 37. One of them is distinguished by the letter *A* and named "Algue calcaire (?)" by Hovelacque; another in the right lower quadrant of the figure is very similar to the oblique sections of the African fossil. The specimens figured by Hovelacque are Urgonian, and are therefore older than the African fossil.

A certain similarity is also exhibited by a fossil figured by Parona (1910, fig. 7) and determined as a radiole of *Cidaris*. Radioles of Echinoidea have been mistaken repeatedly for Dasycladaceae. For instance, the Silurian *Bolboporites*, as originally described by Pander, was thought closely related to *Dactylopora*, to which it does not bear any resemblance (compare Wanner, 1920, p. 806). Rothpletz treats several similar cases thoroughly (1891). None of the radioles described in his paper are identical with our specimens, but they agree in the general structure, characterised by radial plates and an axial perforation. The conclusion, that "*Actinoporella cretacica*" is an echinoderm, is corroborated by examination in polarized light. All its parts show the same crystallographic orientation—the optical axis is parallel to the long axis of the fossil. (I have to thank Hofrat H. Michel for his help in establishing this fact.)

Having thus recognized that "*Actinoporella cretacica*" is the radiole of some echinoid, I tried to reach a closer determination with the help of the well known paper by Hesse (1901). Our fossil clearly belongs to his *Spatangus* type, characterised by one row of tangential pores only, by the lack of calcareous structures connecting the radial plates, by very small size, etc. Within this type three groups are distinguished. "*A. cretacica*" agrees best with the *Brissomorpha* group, the outer edge of the radial plates being rounded, not flat. Several Cretaceous genera bear radioles included in this group, e.g., *Micraster*, *Hemiaster* (common in the Cenomanian of Tripoli according to Checchia-Rispoli, 1921, p. 30), *Ananchytes*, *Hemipneustes*. All these genera seem to be distinguished from the present fossil by much larger pores arranged more regularly. In all probability, however, "*A. cretacica*" is a radiole belonging to some member of the families Holasteridae or Spatangidae.

A very similar type of radiole is common in Eocene rocks and has been occasionally submitted to me as one of the Dasycladaceae. Comparable fossils are present also in Paleozoic rocks (compare Kaisin, 1925, p. 1253, pl. 28, fig. 8).

BOUEINA PYGMAEA Pia, n. sp.
Plate 5, figures 1–9

Boueina hochstetteri RAINERI (not Toula), *1922*, p. 72, pl. 3, figs. 1–4.

The diameter of the thallus is between 0.5 and 0.9 mm., whereas the typical *Boueina hochstetteri* has a diameter of 2.5 to 3.5 mm. (Toula, 1883, p. 1322). The tubes in the center of the thallus hardly reach a width of 0.05 mm., being one-third to one-fourth of their greatest size in the type of the genus (Steinmann, 1901, p. 63). I can not agree with Miss Raineri, who considers these striking differences to be of no systematic value, and prefer to give a new name to the Libyan specimens. As no bifurcation of the thallus was ob-

EXPLANATION OF PLATE 5

FIGS. *1–9*—Sections through the skeleton of *Boueina pygmaea* Pia, n. sp., ×42. *1, 2, 4–6, 9* from the Upper Cretaceous of Teghrenna, near Tripoli, Libya, North Africa; *3* from Msellata-Homs, *7, 8* from the Wadi Msaaba. *9* from Miss Raineri's slide 5; *2, 6*, from slide 6; *8* from slide 13; *7* from slide 14; *1, 5* from slide 17; *4* from slide 18; *3* from slide 20. Drawings by the author. (p. 12)

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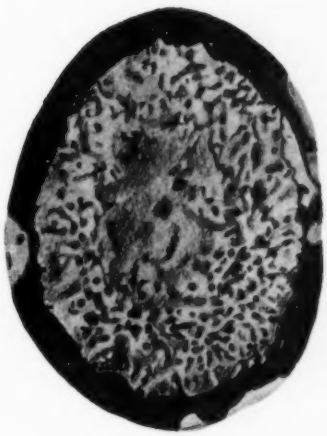

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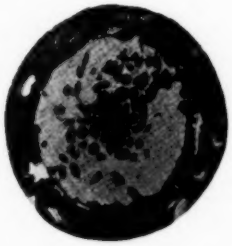

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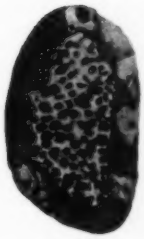

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served, the specimens probably belong to *Boueina*, not to *Halimeda*. As already mentioned (Pia, Pfender, and Termier, 1932, p. 16), they are distinguished from *Halimeda nana* by the smaller size of the tubes. I could not detect a well defined cortical layer, but this may be a matter of preservation. As Miss Raineri has already noted, the calcification is often incomplete, leaving the central part of the thallus uncalcified (Pl. 9, figs. 7, 9). This axial cavity is essentially different from the one found in the Dasycladaceae, as it certainly did not contain a single, large axial cell.

Boueina pygmaea has been found in the following localities: Teghrenna, Wadi Msaaba, and Msellata-Homs.

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SOME HAMILTON (DEVONIAN) CRINOIDS FROM NEW YORK

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ABSTRACT

Crinoids from the Devonian Hamilton group of New York included in a recent collection represent 14 species in 11 genera; the orders Camerata, Flexibilia, and Inadunata are represented. Five species and one genus are new.

A small collection of New York Hamilton crinoids recently studied includes several interesting new forms and adds to our knowledge of species already described. This collection was submitted by Doctor G. Arthur Cooper, of the U. S. National Museum, Washington, D.C. In the summary list that follows the species are grouped according to order and family, and with each name is given stratigraphic position and the locality.

Summary list of Hamilton crinoids described in this paper

Order CAMERATA Wachsmuth and Springer.
Family RHODOCRINIDAE Roemer.

1. *Gilbertsocrinus intersculptus* Goldring, n. sp. Skaneateles (Berwyn); Palmer's Ravine, West Edmeston, Unadilla Valley.
2. *Gilbertsocrinus* cf. *G. alpenensis* Ehlers. Ludlowville; Lebanon.
3. *Gilbertsocrinus rarispinus* Goldring, n. sp. Moscow; Werner's Quarry, Georgetown.
4. *Thylacocrinus clarkei* Wachsmuth and Springer. Moscow (Kashong); Menteth Point, Canandaigua.

Family MELOCRINIDAE Zittel em. Wachsmuth and Springer.

5. *Melocrinus ornatus* Goldring, n. sp. Skaneateles; Palmer's Ravine, West Unadilla Valley.
6. *Melocrinus* n. sp. Hamilton; Unadilla Valley.
7. *Dolatocrinus springeri* Goldring, n. sp. Ludlowville (Centerfield): East Bethany.

Family BATOCRINIDAE Wachsmuth and Springer.
Subfamily PERIECHOCRININAE Springer.

8. *Megistocrinus depressus* Hall. Moscow (Kashong); Menteth Point, Canandaigua.

Subfamily BACTOCRININAE Springer.

9. *Aorocrinus formosus* Goldring. Moscow (Kashong); Menteth Point, Canandiagua.

Family HEXACRINIDAE Wachsmuth and Springer.

10. *Arthracantha* cf. *A. ithacensis* Williams. Moscow; Werner's Quarry, Georgetown.

Order FLEXIBILIA Zittel.
Suborder TAXOCRINOIDEA Springer.
Family TAXOCRINIDAE Bather em. Springer.

11. *Eutaxocrinus* cf. *E. whiteavesi* Springer. Ludlowville (Wanakah); Cazenovia Creek, Spring Brook.

Order INADUNATA Wachsmuth and Springer.
Suborder LARVIFORMIA Wachsmuth and Springer.
Family PISOCRINIDAE Angelin.

12. *Perissocrinus papillatus* Goldring, n. gen. and sp. Ludlowville (Centerfield); Dean Creek, top of Goulds Falls, Aurora.

Suborder FISTULATA Wachsmuth and Springer.
Family POTERIOCRINIDAE Roemer em. Wachsmuth and Springer.

13. *Poteriocrinus? dignatus* Goldring. Moscow; Schatz Brook, New Berlin.
14. *Logocrinus geniculatus* Goldring. Moscow; Werner's Quarry, Georgetown.

In the succeeding part of this paper the new forms alone are fully described. Forms tentatively placed are briefly discussed, and for previously described forms only additional data are given.

All material studied is in the U. S. National Museum, Washington, D.C.

SYSTEMATIC DESCRIPTIONS

Genus GILBERTSOCRINUS Phillips

Four Hamilton species of *Gilbertsocrinus* have been previously described—from Clark County, Indiana: *G. greenei* Miller and Gurley, *G. indianensis* Miller and Gurley; from the Moscow of Ontario County, western New York: *G. spinigerus* (Hall); from the Hamilton near Alpena, Michigan: *G. alpenensis* Ehlers. As pointed out by the writer in another paper (1), *G. indianensis* is synonymous with *G. spinigerus*. *G. greenei* differs from *G. spinigerus* in the absence of a spine on the first primibrach; *G. alpenensis*, among other things, in the absence of a spine on the primary interbrachial. *G. spinigerus* is characterized by prominent spines on the radials, first primibrachs and primary interbrachials, in addition to the prominent radial ridge. In one of the New York types the arms, so far as preserved, are uniserial and four to the ray.

In the collection described here *Gilbertsocrinus* is represented from the Skaneateles, Ludlowville and Moscow formations. The three species show a progressive decrease in ornamentation and in prominence and number of spines, together with a decrease in the number of arms, which, so far as preserved, are biserial. The Skaneateles form has very prominent, strong spines on the radials and first primibrach, a low radial ridge and quite distinct radiating ridges on both radial and interradial plates; arms normally six to the ray, usually three to each half ray, biserial. The species from the Ludlowville formation, tentatively referred to *G. alpenensis*, is a smaller form with prominent spines on radials and first primibrachs, a comparatively prominent radial ridge and plates smooth or practically so; arms normally four to a ray, biserial. Only one fragmentary specimen represents the Moscow species; the radials bear a prominent spine and the plates of the dorsal cup are smooth, so far as preserved. This is a very interesting series, which it is to be hoped will be increased.

GILBERTSOCRINUS INTERSCULPTUS Goldring, n. sp.

Plate 6, figures 1–6

Dorsal cup fairly large; height below the arm bases, 14 mm.; greatest width, at the first primibrachs, about 19 mm. Cup pentagonal in cross-section, constricted at the arm bases, expanding slightly above.

Basal pit deep, with the basals forming the sides. First primibrachs considerably larger than primaxils, of about the size of the radials. Primary interbrachial smaller than radials, apparently followed by the series 3, 3, 3, 2. Secundibrachs 2×10; the second axillary, giving rise on the inner side to an arm, on the outer to an interradial appendage. Intersecundibrachs 3 or more, 1 in the first row and 2 in the second. Each arm bifurcates on the third tertibrach; the inner arm again on the third quatribrach, giving 3 arms to the half ray or 6 arms to the ray, normally. In one specimen two rays show a variation from the normal bifurcation. In one ray one arm bifurcates once, giving 2 arms to the half ray; the other bifurcates twice, giving 4 arms to the half ray; a total of 6 to the ray. In a second ray one half ray has 2 arms, the other 3, giving 5 arms to the ray. Arms compactly biserial; pinnules long, composed of long ossicles.

Tegmen low, composed of numerous small plates rather irregularly arranged, distinctly nodose in the oral region and

somewhat so in the ambulacral areas. Interradial tubular appendages composed of a single series of longitudinal, cylindrical joints, united for at least 3 or 4 plates, not recurved.

Column comparatively large; diameter approximately 5 mm. in largest specimen.

The ornamentation in this species is very striking. Large, prominent spines are present on the radials and primibrachs, and a radial ridge forks on the primaxil and follows up to the arms. The radial ridges are more striking in the younger forms where the spines are less strongly developed. The plates of both radial and interradial series are marked by distinct radiating ridges, stronger in younger individuals and on the interradial plates. The ornamentation of the tegmen consists of small nodes on the plates of the ambulacral and oral areas.

Horizon and locality.—Skaneateles formation (Berwyn member), Palmer's Ravine, West Edmeston, Unadilla Valley, New York.

Remarks.—*G. intersculptus* may be readily distinguished from *G. spinigerus* in the greater number of arms, which are also biserial, the absence of a spine on the primary interbrachial, and the strong radiating ridges on the radial and interradial plates. *G. greenei* has a spine on the primary interbrachial but lacks the spine on the first primibrach and the ornamentation of radiating ridges.

GILBERTSOCRINUS cf. G. ALPENENSIS Ehlers

Plate 6, figures 7–10

The specimens discussed here are tentatively referred to *G. alpenensis* Ehlers, described from the Hamilton of Alpena, Michigan (2), and based on an imperfect specimen, the basal part of a dorsal cup including the primaxils. The fine granulation on the outer surfaces of the plates of the dorsal cup and the extremely low nodes on some of the interbrachials, noted in the original description, have not been seen in the New York material, but these specimens are not particularly well preserved. Our material adds information as to the character of the cup above the primaxil, the tegmen, and the arms.

This species appears to be smaller and more delicate than *G. intersculptus*, judging from the material at hand. The prominent spines on the radials and first primibrachs are present and also the radial ridge, but the radiating ridges on radial and interradial plates are missing. The second secundibrach in each half ray gives rise to the tubular appendage on the outer side and on the inner side to an arm that bifurcates on the third tertibrach, giving 4 arms to the ray in contrast to the 6 of *intersculptus*. In the largest specimen, which shows the tegmen from the under side, 1 ray, apparently the left posterior, has 3 arms in

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EXPLANATION OF PLATE 6

FIGS. *1–6*—*Gilbertsocrinus intersculptus* Goldring, n. sp., Skaneateles formation (Berwyn member), Palmer's Ravine, West Edmeston, Unadilla Valley, New York, U. S. Nat. Mus. 90,068. *1, 2*, Mold and plasticine squeeze of a large specimen. *3*, Squeeze of specimen showing part of tegmen, ventral side of arms, and tubular appendages. *4*, Squeeze of a crown, ×2, showing pinnules. *5*, Squeeze of a young specimen showing the ornamentation of the interradial areas. *6*, Squeeze of a crushed crown, showing arms and parts of tubular appendages. (p. 15)

7–10—*Gilbertsocrinus* cf. *G. alpenensis* Ehlers, Ludlowville formation, Lebanon, New York; U. S. Nat. Mus. 90,067. *7*, Plasticine squeeze of crown and column of a small specimen showing anal interradius, proximal portions of arms, and tubular appendage. *8*, Squeeze of part of a crown and of a portion of the column of another specimen. *9, 10*, Mold, ×1, and squeeze, ×2, of tegmen seen from underside, dorsal side of arms and tubular appendages of a large specimen. (p. 16)

11—*Gilbertsocrinus rarispinus* Goldring, n. sp., Moscow formation, Werner's Quarry, Georgetown, New York; U. S. Nat. Mus. 90,069; plasticine squeeze of lower portion of basal cup, ×2. (p. 17)

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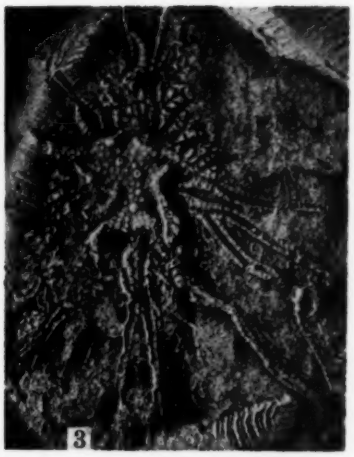
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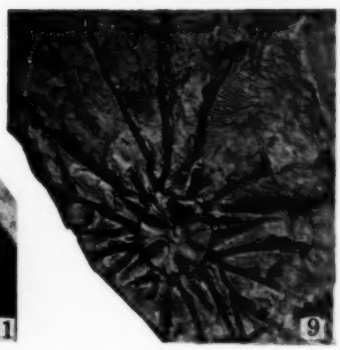
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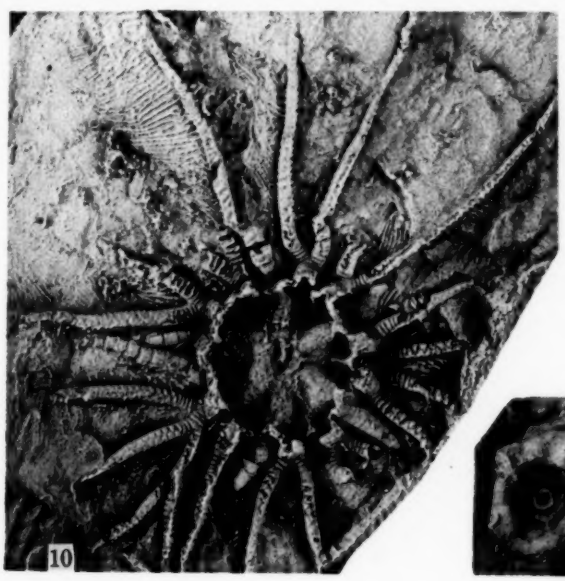
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Goldring, Devonian Crinoids

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one half-ray (toward posterior interradius) and 1 in the other. The arms are compactly biserial with long pinnules. In the posterior interradius the tubular appendages are shown separated by the anal plates. The tegmen, preserved in only one specimen, and in that only from the under side, is low and composed of numerous small plates.

Horizon and locality.—Ludlowville formation, Lebanon, New York.

GILBERTSOCRINUS RARISPINUS
Goldring, n. sp.
Plate 6, figure 11

A portion of one dorsal cup preserving the posterior interradius and the secundibrachs in the right posterior radius represents this species. Ordinarily such material would be too fragmentary to justify a specific name, but in this case the species may be identified if only part of the dorsal cup is preserved. It differs from all other species of *Gilbertsocrinus* in having a prominent spine on the radials alone. Basal pit deep, the sides being formed by the basals. Infrabasals small, about one-third of the height of the basals, lying in the bottom of the basal pit. Column comparatively slender, judging from the attachment, with large axial canal. Radial ridge not strongly developed, but more prominent above the primaxil. Neither radial nor interradial plates have radiating ridges.

Horizon and locality.—Moscow formation, Werner's Quarry, Georgetown, New York.

MELOCRINUS ORNATUS
Goldring, n. sp.
Plate 7, figure 1

A sturdy form with relatively large, strong stem. The single specimen shows only two radial series, two interradii and part of a third, but the shape of the calyx and the ornamentation are so characteristic that there should be no difficulty in identifying the species.

Calyx obconical, apparently wider than high, showing a sharply pentagonal section across the radials and primibrachs. Radial series marked by a very prominent ridge, that forks on the primaxil and extends to the secundibrachs; interradii depressed, flat to slightly concave. Basals forming a low cup, projecting slightly beyond the column. Radials wider than high; first primibrach nearly as large as the radial, of about equal height and width. Primaxils about two-thirds the size of the primibrach, somewhat higher than wide and supporting 2×10 secundibrachs (shown in one ray). In two rays the secundaxil bears on the outside one tertibrach that may give rise to an auxiliary arm; in one ray on the inside 2 tertibrachs are followed by 3 plates of the main trunks or arms. Primary interbrachial of about the size of the radial, followed by 2 plates in the second range, 3 in the third and apparently 3 in the fourth. Column round, of alternating thick and thin plates.

The prominent ridges on the radial series and the thick radiating ridges on all plates, of both the radial series and the interradii, constitute a very striking ornamentation that will make this species readily identifiable.

Horizon and locality.—Skaneateles formation, Palmer's Ravine, West Edmeston, New York.

Remarks.—The young specimen tentatively referred by the writer to *Melocrinus naplesensis* Goldring (3), resembles *M. ornatus*, but differs in the more tumid basals, the more or less granular surface of some of the plates, and the formation of the radiating ridges from coalesced bead-like elevations. The nodal columnals are somewhat nodose.

MELOCRINUS n. sp.
Plate 7, figure 2

This fragmentary specimen is nearest to *Melocrinus splendens* Goldring (4) from the Chemung beds. From the portion preserved the cup might be expected to be broader than high, somewhat hemispheric or bowl-shaped. Parts of two radii, from the first primibrach to and

including the bases of the arm trunks, parts of two interradii and some of the tegminal plates remain. A prominent rounded ridge follows the radial series, bifurcating on the primaxil, broadening out on the first secundibrachs and occupying practically the entire width of the second and third secundibrachs. There is one rather large intersecundibrach. Radial and interradial plates ornamented with quite distinct radiating ridges; prominent spines on the first primibrachs, primaxils and first secundibrachs, with the suggestion of a node on the second secundibrach; radiating ridges and small spines on some of the interambulacral plates of the tegmen, which appears to be somewhat domed. Arm trunks heavy, judging by the bases, apparently free at about the fifth secundibrach.

This form appears to be a good species. The radiating ridges, lighter than in *M. splendens*, and the spines on the plates of the radial series no doubt distinguish it from the Chemung form; but without more knowledge of the arms or of the dorsal cup a new specific name is not justified.

Horizon and locality.—Hamilton of Unadilla Valley, New York. C. B. Hunt, collector.

Dolatocrinus springeri
Goldring, n. sp.

Plate 7, figures 3–5

A single specimen represents this very characteristic species. Small, with greatest diameter, 11.8 mm., at first primibrachs. Cup low, about 5 mm. high, spreading horizontally to top of radials. Basals small, concealed at bottom of the deep basal depression into which column fits. Radials larger than primibrachs; upper and lower lateral faces about equal, making the radial of about the same width at top and bottom; almost the lower two-thirds of radials embraced in basal depression. First primibrachs short, not as broad as radials; nearly as high as broad. Primaxils broader at top than first primibrachs but not so high; with long sloping shoulders to support the 2×5 secundibrachs which are large,

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Explanation of Plate 7

Fig. *1*—*Melocrinus ornatus* Goldring, n. sp., Skaneateles formation, Palmer's Ravine, West Edmeston, New York; U. S. Nat. Mus. 90,069; plasticine squeeze of portion of calyx and column. (p. 17)

2—*Melocrinus* n. sp., Hamilton group, Unadilla Valley, New York; U. S. Nat. Mus. 90,072; plasticine squeeze of portion of calyx. (p. 17)

3–5—*Dolatocrinus springeri* Goldring, n. sp., Ludlowville formation (Centerfield member), East Bethany, New York; U. S. Nat. Mus. 90,080; tegmen, lateral and basal views of dorsal cup, ×2. (p. 18)

6—*Perissocrinus papillatus* Goldring, n. gen. and sp., Ludlowville formation (Centerfield member), Dean Creek, top of Gould's Falls, Aurora, New York; U. S. Nat. Mus. 90,076; dorsal cup from posterior side, ×2, with anal (*x*) at left. (p. 21)

7, 8—*Aorocrinus formosus* Goldring, Moscow formation (Kashong member), Menteth Point, Canandaigua, New York; U. S. Nat. Mus. 90,071; crown of mature specimen. *7*, Lateral view, posterior interradius at right. *8*, Opposite side, showing right posterolateral and right anterior radii. (p. 19)

9—*Eutaxocrinus* cf. *E. whiteavesi* Springer, Ludlowville formation (Wanakah member), Cazenovia Creek, Spring Brook, New York; U. S. Nat. Mus. 90,074; lateral view of crown with left posterior ray at right. (p. 20)

10, 12—*Poteriocrinus? dignatus* Goldring, Moscow formation, Schatz Brook, New Berlin, New York; U. S. Nat. Mus. 90,079; plasticine squeezes of calyx, posterior and anterior views, ×2. (p. 22)

11—*Arthracantha* cf. *A. ithacensis* Williams, Moscow formation, Werner's Quarry, Georgetown, New York; U. S. Nat. Mus. 90,077; plasticine squeeze of part of calyx, ×2. (p. 19)

13—*Logocrinus geniculatus* Goldring, Moscow formation, Werner's Quarry, Georgetown New York; U. S. Nat. Mus. 90,075; plasticine squeeze of part of crown, lateral view showing anal tube, ×2. (p. 22)

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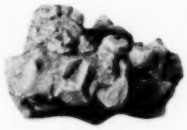

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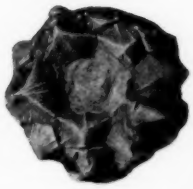

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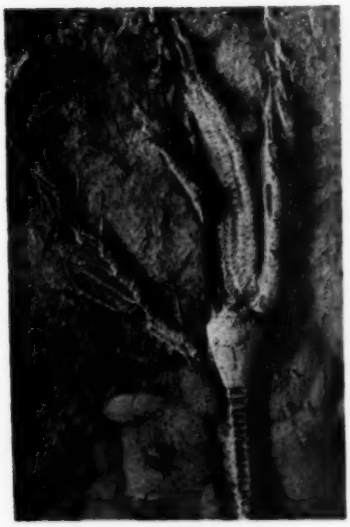

13

Goldring, Devonian Crinoids

UNIV. OF MICH.

but not axillary. Arms free above first secundibrachs, apparently 10.

Primary interbrachial higher than wide, bordered by radials, first primibrachs, primaxils and first secundibrachs, and followed, apparently, by one plate. Tegmen flat with depressed interambulacral areas, giving a lobed aspect; plates of fairly large size; small spinose tubercles present, particularly on the ambulacral areas but somewhat scattered over the interambulacral areas also. Anal tube stout and excentric; only the proximal portion preserved.

Ornamentation of dorsal cup very striking. Surface of all plates rugose, particularly primary interbrachials and secundibrachs. Faint but distinct radiating carinae on the radial series and interbrachials, but the excessive development of spines or spinose nodes has obscured them as well as the radial ridge. The spine or spinose node on each radial triangular, taking up the entire surface, one edge following the radial ridge, the others with the corresponding edges of the neighboring radials forming the boundary of the basal depression. Spine on the first primibrach more prominent, sharper and curved upward; on primaxil low and blunt; on primary interbrachial large, rather sharp and distinctly curved upward.

This species has been named in honor of the late Doctor Frank Springer, who monographed the genus *Dolatocrinus* and its allies (5). The size and character of the dorsal cup, together with the peculiar development of spines distinguishes the species from all others.

Horizon and locality.—Ludlowville formation (Centerfield), East Bethany, New York.

Megistocrinus depressus Hall

The single specimen representing this species is a large, fairly well-preserved adult form showing the arms, the first adult individual in which the arms are preserved. Three young individuals with arms preserved were described and figured by the writer (6). In them the arms are comparatively slender; compactly biserial with rounding backs and sides; with long, slender and closely crowded pinnules. In these young crinoids there is but a single bifurcation after the arms become free. The writer stated that at maturity many more bifurcations were to be expected, as in the closely allied *M. ontario*, in which as many as five have been counted. The specimen under discussion justifies this expectation. The arms are long (80 to 90 mm. preserved) and slender, of the same character as seen in the young specimens, and bifurcate at least four times after becoming free.

Horizon and locality.—Moscow formation (Kashong member), Menteth Point, Canandaigua, New York.

Aorocrinus formosus Goldring

Plate 7, figures 7, 8

This is a more mature individual than any specimen previously described by the writer (7). The ridges on the radial series are more prominent than in the younger forms and the nodes and radiating ridges on both radial and interradial plates are better developed.

Horizon and locality.—Moscow formation (Kashong member), Menteth Point, Canandaigua, New York.

Arthracantha cf. A. ithacensis Williams

Plate 7, figure 11

In shape and size of cup the single specimen resembles *A. ithacensis*. The basal and radial plates have practically the same measurements as in the type (8), and the spine-bearing tubercles on these plates also correspond in size, arrangement, and number. Apparently, parts of three interradial plates are shown in one interradius. Whether the arms are loosely biserial as in *A. ithacensis* cannot be ascertained, since the arms are preserved only as far as the second secundibrach.

Horizon and locality.—Moscow formation, Werner's Quarry, Georgetown, New York.

EUTAXOCRINUS cf. E. WHITEAVESI Springer

Plate 7, figure 9

The crown of this specimen is preserved to a height of 20 mm., with a width at that height of 15 mm. Infrabasals low, slightly exposed beyond the column. Surface of all plates smooth. Margins of brachials flanged, sutures strongly arcuate. Arms strong, broadly rounded below, diminishing rapidly with each bifurcation, lying close together but not abutting. In the rays best preserved (left posterior and left anterolateral) secundibrachs 3 or 4. Tertibrachs, determinable in only one ray, 5 on the inner branch, 6 on the outer. Only 4 quatribrachs preserved. Anal tube apparently small.

The original description of this species was based upon material from the Hamilton group, Thedford, Ontario. So far as is known to the writer, the specimen discussed here is the first record of the species in the New York Hamilton.

Horizon and locality.—Ludlowville formation (Wanakah member), Cazenovia Creek, Spring Brook, New York.

Genus PERISSOCRINUS Goldring, n. gen.

Etymology: περισσὸς, extraordinary; χρίνον, lily.

An inadunate, monocyclic crinoid. Basals 5; radials 5, all compound—the right posterior and right and left anterior bisected horizontally; the anterior and left posterior, obliquely. Anal plate in dorsal cup, between the posterior radials. Radial facets shallow, concave, filling the greater part of distal face of the radials. Arms apparently simple; tegmen unknown.

Only a single specimen of this peculiar crinoid is known. It is asymmetrical, marked by a slight gibbosity at the posterior side; but apparently is not abnormal. Every suture is distinct, except in the left anterior radius where the calyx is somewhat broken. *Perissocrinus* bears a superficial resemblance to the genus *Hypsocrinus*, created by Springer and Slocom (9) for a single specimen from the Hamilton group of East Bethany, New York. In *Hypsocrinus*, which shows a gibbosity at one side, the right posterior, right anterior, and perhaps anterior, radials are compound; there is no anal plate in the dorsal cup, but the lower segment of the right posterior radial is considered to be probably a radianal. The radial facets are similar to those in *Perissocrinus*, and the arms are simple and non-pinnulate.

Perissocrinus and *Hypsocrinus* belong to the suborder Larviformia, a small group of irregular inadunate crinoids represented in the Silurian by *Pisocrinus* and in the Devonian by *Triacrinus*, *Haplocrinus*, and *Calycanthocrinus*. In *Pisocrinus*, *Triacrinus*, and *Haplocrinus* the radial facet occupies a small, squarely-mortised socket in the middle of the plate; in *Perissocrinus* and *Hypsocrinus* the radial facet is broad and shallow and fills a large part of the distal face of the radial. Though the radial facets in *Calycanthocrinus* are somewhat similar to those of *Perissocrinus*, *Calycanthocrinus* has several supplementary arm-bearing radials in addition to the regular five.

Perissocrinus is tentatively placed with *Hypsocrinus* in the family Pisocrinidae, with which it shows the most affinity, though the genus differs from other genera of the family in that the anal or first tube plate is sunk between the posterior radials. In this feature *Perissocrinus* is more like the Symbathocrinidae. The most primitive symbathocrinid genus, *Phimocrinus*, has five basals, whereas all the other genera have three; and the oldest species, *P. jouberti* Oehlert, as pointed out by Springer and Slocum in an interesting comparison with *Hypsocrinus*, shows clear traces of an horizontal suture in the right posterior, right anterolateral, and left anterolateral radials—the usual compound radials in *Haplocrinus*, *Heterocrinus*, and similar forms. Springer and Slocum (9) remark:

This species [*P. jouberti*], therefore, represents a form which in its younger stage would have fallen into the same group of irregular crinoids as our genus (*Hypsocrinus*), but in which, by growth during life, the radials were eliminated, and the crinoid modified into a regular form. *Phimocrinus* has straight radial facets, filling the entire distal face of the radials, and the arms articulate on a linear hinge line.

The anal or first tube plate rests upon the shoulders of the posterior radials.

Genotype: *P. papillatus* Goldring, n. sp.

PERISSOCRINUS PAPILLATUS
Goldring, n. sp.
Plate 7, figure 6

Calyx elongate, slightly expanding to the arm bases; height, 15 mm.; width at top, 9 to 10 mm.; width at base, 4.5 mm. Base truncate; basal facet occupied entirely by the column, of which one pentagonal columnal remains; axial canal pentagonal, the angles radial in position.

Basals elongate, practically equal in size and shape, 5.8 mm. to 6 mm. high, or about two-fifths of the height of the cup. Radials 5, compound, differing somewhat in shape and width; heights from 8.7 mm. to 9.8 mm. (right posterior), all arm-bearing. Right posterior and left anterolateral infer-radials are heptagonal; anterior and left posterior, hexagonal; right anterolateral, pentagonal, noticeably smaller than the others because encroached upon by the large right posterior infer-radial, which joins it with a curved suture. Infer-radials constitute five-eighths to two-thirds the height of the compound radials, which are bisected horizontally in the right posterior, right anterolateral and left anterolateral rays; obliquely in the anterior and left posterior rays. Superradials all of about the same size; arm-facets shallow, curved, not entirely filling the distal faces of the radials but leaving short, sloping shoulders rounded off exteriorly. No more than three proximal brachials of any arm preserved; apparently simple. Anal plate as large as the super-radials, apparently followed by one large plate, for the distal face is straight and occupies practically the full width of the plate. Tegmen unknown. Surface of all plates of the dorsal cup covered with numerous small papillae, hence the specific name. Stem unknown; proximal columnal attached to calyx pentagonal, 3.7 mm. in diameter.

Horizon and locality.—Ludlowville formation (Centerfield member), Dean Creek, top of Goulds Falls, Aurora, New York.

Remarks.—The resemblance of this form to *Hypsocrinus fieldi* at first glance is very striking. For comparison with *Perissocrinus papillatus* the analysis of the calyx of the former is given here.

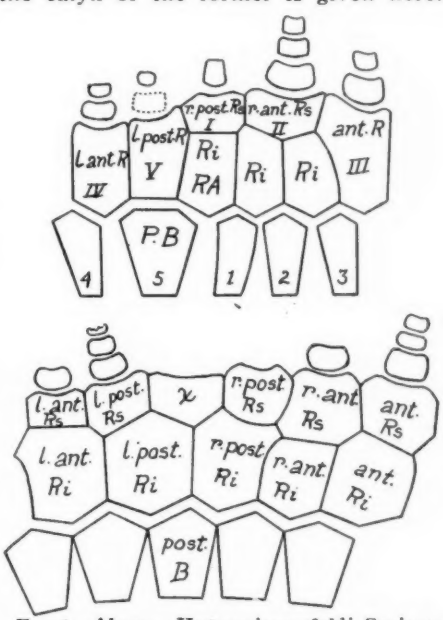

FIG. 1—Above, *Hypsocrinus fieldi* Springer and Slocum, analysis of calyx, ×2, after Springer and Slocum. Below, *Perissocrinus papillatus* Goldring, n. gen. and sp., analysis of calyx, ×2. *R*, radial; *Rs*, super-radial; *Ri*, infer-radial; *RA*, radianal; *ant.*, anterior; *r. ant.*, right anterolateral; *l. ant.*, left anterolateral; *r. post.*, right posterior; *l. post.*, left posterior; *x*, anal or first tube plate; *P.B.*, posterior basal.

POTERIOCRINUS? DIGNATUS
Goldring

Plate 7, figures 10, 12

The larger part of the dorsal cup is preserved and two primibrachs in one ray. This specimen shows 5 mm. of stem not shown in the type. The stem is crushed, but apparently somewhat pentangular; composed of alternating thin and thick columnals, slightly thickened at the angles.

Horizon and locality.—Moscow formation, Schatz Brook, New Berlin, New York.

LOGOCRINUS GENICULATUS Goldring

Plate 7, figure 13

A single specimen showing parts of two arms, one side of the calyx, and for the first time, to the writer's knowledge, the anal tube. The tube is slender; consists of vertical rows of low, broad plates; and apparently has a median dorsal ridge extending its full length. The arms show three primibrachs, the zig-zag habit, and long pinnules with long ossicles borne on every second brachial.

Horizon and locality.—Moscow formation, Werner's Quarry, Georgetown, New York.

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Note: The manuscript of this paper was received by the editor of the Journal May 10, 1935.

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CAMBRIAN TRILOBITES FROM NORTHWESTERN WYOMING

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ABSTRACT

A brief discussion of the stratigraphy of the Cambrian of northwestern Wyoming is followed by the description of 5 genera and 21 species of trilobites, of which 4 genera and 16 species are new.

Field studies by the writer in the Cambrian formations of northwestern Wyoming have disclosed undescribed trilobites and extended the geographic range of genera and species not previously reported from the Rocky Mountain region. Most of the new forms are described in this paper, and a number of genera and species, previously described but not reported from Wyoming, are illustrated.

Acknowledgments.—The writer wishes to express to Dr. G. M. Kay and to Dr. H. N. Coryell his appreciation of their criticisms and suggestions. The large collections of fossils at the U. S. National Museum were used for comparative studies, and the writer is indebted to the paleontologists at that institution, particularly Dr. C. E. Resser, for their courtesies in that regard. Dr. G. O. Raasch kindly supplied specimens of certain Wisconsin forms for similar comparisons. The advice and assistance of Mr. M. P. Landman have been especially valuable in the preparation of the plates.

The manuscript of the paper was received by the editor of the Journal June 4, 1935.

STRATIGRAPHIC SUMMARY

The writer's field work, carried out as part of the program of the Geological Survey of Wyoming, consisted primarily in tracing the Flathead, Gros Ventre, and Gallatin formations from the Teton Mountains, south of Yellowstone Park, eastward through the Gros Ventre Range and northwestern Wind River Mountains into the so-called "Deadwood" formation of the Owl Creek-Bridger uplift. The following outline presents only the more important conclusions, for the details are given in a separate paper now in press.

The Flathead formation, 175 feet in average thickness, consists of sandstone and quartzite; the overlying Gros Ventre formation, 675 feet in average thickness, consists largely of shale. The Gros Ventre contains in the lower part a persistent limestone member to which the name Death Canyon member has been applied by the writer; this member attains a thickness of 285 feet in the Teton Mountains, gradually thins and interfingers with shale toward the east, and disappears in the middle parts of the Owl Creek and Wind River Mountains. Toward the east also rock types characteristic of the Flathead formation appear at progressively higher horizons in the lower part of the Gros Ventre forma-

tion, the sandstone and shale facies becoming so mixed that the two formations are not separable and the combined units have been designated the Depass formation. The type section of the Depass is in Wind River Canyon, at the eastern end of the Owl Creek Range, and the formation is defined to include all the beds in the so-called "Deadwood" formation below the Gallatin formation.

The Gallatin formation, overlying respectively the Gros Ventre and Depass formations, consists of a lower limestone member, a middle shaly member, and an upper limestone member. The formation maintains its lithologic identity from the Teton Mountains eastward into the Bridger Mountains, where it forms the upper 300 feet of the so-called "Deadwood." The name Du Noir member has been applied by the writer to the lower member, which consists largely of massive, oolitic limestone.

The Du Noir member contains an early Late Cambrian Eau Claire fauna at its base, from which fact it is inferred that the pre-Gallatin formations are largely of Medial Cambrian age. This conclusion is in part verified by the presence of Medial Cambrian trilobites in the Gros Ventre, although it is believed that the upper 75 or 100 feet of the Depass and Gros Ventre formations in the Wind River, Owl Creek, and Bridger mountains is approximately equivalent to the Mt. Simon formation, which underlies the Eau Claire formation in the type St. Croixian series and contains no fauna.

SYSTEMATIC DESCRIPTIONS

Order OPISTHOPARIA Beecher

Genus ARAPAHOIA Miller, n. gen.

Genotype: *Arapahoia typa* Miller.

Cranidium gently convex, flattened, nearly smooth, characterized by flaring base and linguloid outline anterior to the small palpebral lobes. All furrows weak or absent except the occipital furrow, which is moderately strong, anteriorly arcuate on the axis and usually wider, more deeply impressed in its extensions across the posterior limbs. Glabella barely discernible, very slightly elevated and in some species practically flush with the fixed cheeks; glabellar furrows absent. Brim one-third to one-half as long as the glabella exclusive of the occipital furrow and ring, usually without trace of frontal furrow; in some species brim continuous with glabella; in other species brim faint but clearly defined and may show traces of separation into border and rim. Occipital ring triangular, bulbous, produced into a short, slender spine which is usually broken off. Eye-lines absent. Fixed cheeks, thorax, and pygidium unknown. Surface smooth.

Comparisons.—Arapahoia and *Plethometopus* Ulrich, 1930, are similar in that both have smooth cranidia and similar occipital rings. The cranidium of *Arapahoia*, however, is much less convex, and the flaring base and linguloid character anterior to the eyes are distinctive. The occipital spine of *Arapahoia* is longer and more slender than that of *Plethometopus*.

Formation and locality.—Arapahoia appears to be the most common trilobite genus in the upper 50 feet of the Depass formation in the Owl Creek and Bridger Mountains and has been found at approximately the same stratigraphic position in the Cambrian of the Big Horn Mountains. A single species has been found in the basal glauconitic limestones of the Du Noir member of the Gallatin formation in the northwestern part of the Wind River Mountains.

ARAPAHOIA TYPA Miller, n. sp.

Plate 8, figure 6

Cranidium moderately and evenly convex. Facial suture directed obliquely outward and backward posterior to the eyes, diverging very slightly anterior to the eyes. Glabella slightly elevated above fixed cheeks, sides converging anteriorly, front rounded. Brim about one-third as long as glabella (exclusive of the occipital furrow and ring), without trace of differentiation into border and rim. Palpebral lobes small, approximately midway between occipital furrow and anterior margin of cranidium. Occipital furrow anteriorly arcuate on the axis, stronger in its extensions across the posterior limbs; occipital ring tapering posteriorly into a short, slender spine.

Formation and locality.—Argillaceous limestone talus blocks 500 feet below the top of the Cambrian; southeast quarter, T. 56 N., R. 92 W., east flank of Medicine Mountain, Big Horn County, Wyoming. The position of the talus blocks is probably 100 feet below the true stratigraphic position at which the species occurs.

Holotype.—Columbia Univ. 12,612.

ARAPAHOIA LEVIS Miller, n. sp.

Plate 8, figures 3, 4

The cranidium of this species is similar in general outline, proportions, and convexity to the cranidium of *A. typa*, from which it differs in that the course of the facial suture is directly forward anterior to the eye, not diverging, as in *A. typa*, and in that the cranidium is practically undifferentiated into fixed cheeks and glabella. The boundaries of the glabellar area are indicated posterior to the eyes by a very slight steepening of the convexity of the cranidium; on specimens coated with ammonium chloride the glabellar area appears slightly lighter in shade than the rest of the cranidium.

Formation and locality.—Gallatin formation, glauconitic limestones at the base of the Du Noir member; Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming.

Holotype.—Columbia Univ. 12,614.

ARAPAHOIA SPATULATA Miller, n. sp.

Plate 8, figure 5

Cranidium flattened-convex. Facial suture flaring widely behind the eyes, delimiting a broad base with posterior limbs directed outward nearly at right angles to axis; facial suture trending directly forward anterior to eyes. Glabella subquadrangular in outline, rounded anteriorly, slightly elevated above fixed cheeks. Brim about half as long as glabella (exclusive of occipital furrow and ring); a triangular rim, about half as wide as the border, is barely traceable. Occipital furrow and ring as in *A. typa*.

Comparisons.—*A. spatulata* differs from *A. typa* and *A. levis* in that the cranidium is proportionately narrower anterior to the eyes and in that the outward deflection of the facial suture posterior to the eyes is much greater and more abrupt.

Formation and locality.—Depass formation, limestones 50 feet below the top; northwest quarter, T. 39 N., R. 92 W., Dry Creek, Fremont County, Wyoming.

Holotype.—Columbia Univ. 12,613.

Genus BLOUNTIA Walcott, 1916

BLOUNTIA GLOBOSA Miller, n. sp.

Plate 8, figures 22–24

Cranidium small, length 5 mm., greatest width 4 mm.; glabella high, extremely convex; circum-glabellar and frontal furrows deeply impressed. Facial suture converging slightly anterior to the eyes, rounding the anterior angles, possibly intramarginal for about one-third the distance to the middle of the rim. Glabella ovoid in outline, globose, highly elevated, not marked by glabellar furrows. Preglabellar area and fixed cheeks narrow, raised into a prominent ridge that entirely bounds the deep, circumglabellar furrow. Frontal furrow strong; rim convex, slightly wider than the pre-

EXPLANATION OF PLATE 8

All figures natural size unless otherwise marked

FIGS. *1, 2*—*Irvingella gibba* Miller, n. sp., holotype, dorsal and side views of cranidium; Gallatin formation, South Fork of Teton Canyon Creek, Teton County, Wyoming. (p. 31)

3, 4—*Arapahoia levis* Miller, n. gen. and sp., holotype, dorsal and side views of cranidium; Gallatin formation, Du Noir member, Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming. (p. 25)

5—*Arapahoia spatulata* Miller, n. gen. and sp., holotype, dorsal view of cranidium; Depass formation, Dry Creek, Fremont County, Wyoming. (p. 25)

6—*Arapahoia typa* Miller, n. gen. and sp., holotype, dorsal view of cranidium; Cambrian, east flank of Medicine Mountain, Big Horn County, Wyoming. (p. 25)

7—*Brachyaspis rhynchina* Miller, n. gen. and sp., holotype, dorsal view of cranidium, ×2; Gros Ventre formation, 120 feet above top of Death Canyon member, Crow Creek Canyon, Fremont County, Wyoming. (p. 28)

8—*Brachyaspis?* sp., dorsal view of cranidium with front broken away but showing outlines of posterior limbs and occipital spine; same horizon and locality as fig. *7*. (p. 28)

9–12—*Crepicephalus? wyomingensis* Miller, n. sp., syntypes, same horizon and locality as fig. *7*. *9, 12*, Dorsal views of cranidia. *10, 11*, Dorsal and side views of a cranidium. (p. 29)

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17—*Glyphaspis* cf. *G. concava* Poulsen, pygidium, Gros Ventre formation, Death Canyon member, South Fork of Teton Canyon Creek, Teton County, Wyoming. (p. 30)

18—*Cedaria* aff. *C. prolifica* Walcott, dorsal view of cranidium; Gallatin formation, Du Noir member, Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming. (p. 28)

19–21—*Marjumia? tetonensis* Miller, n. sp., syntypes, Gros Ventre formation, Death Canyon member, South Fork of Teton Canyon Creek, Teton County, Wyoming. *19*, Dorsal view of cranidium. *20*, Retouched view of cast from a natural mold of a cranidium. *21*, Cast from a natural mold of an associated pygidium. (p. 33)

22–24—*Blountia globosa* Miller, n. sp., syntypes, ×2, same horizon and locality as fig. *18*. *22*, Dorsal view of cranidium. *23, 24*, Dorsal and side views of another cranidium. (p. 25)

25–27—*Blountia dunoirensis* Miller, n. sp., syntypes, same horizon and locality as fig. *18*. *25*, Dorsal view of cranidium, ×1. *26*, Dorsal view of another cranidium, ×2. *27*, An associated pygidium, ×2. (p. 27)

28, 29—*Kingstonia sublettensis* Miller, n. sp., ×2, Gallatin formation, Du Noir member, 1 mile north of Green River Lakes, Sublette County, Wyoming. *28*, Holotype cranidium, dorsal view. *29*, Paratype, associated pygidium. (p. 31)

30–33—*Kyphocephalus bridgerensis* Miller, n. gen. and sp., Gallatin formation, Dry Creek, Fremont County, Wyoming. *32, 33*, Holotype cranidium, dorsal and side views; *30*, Paratype, fragment of associated free-cheek. *31*, Paratype dorsal view of small cranidium. (p. 32)

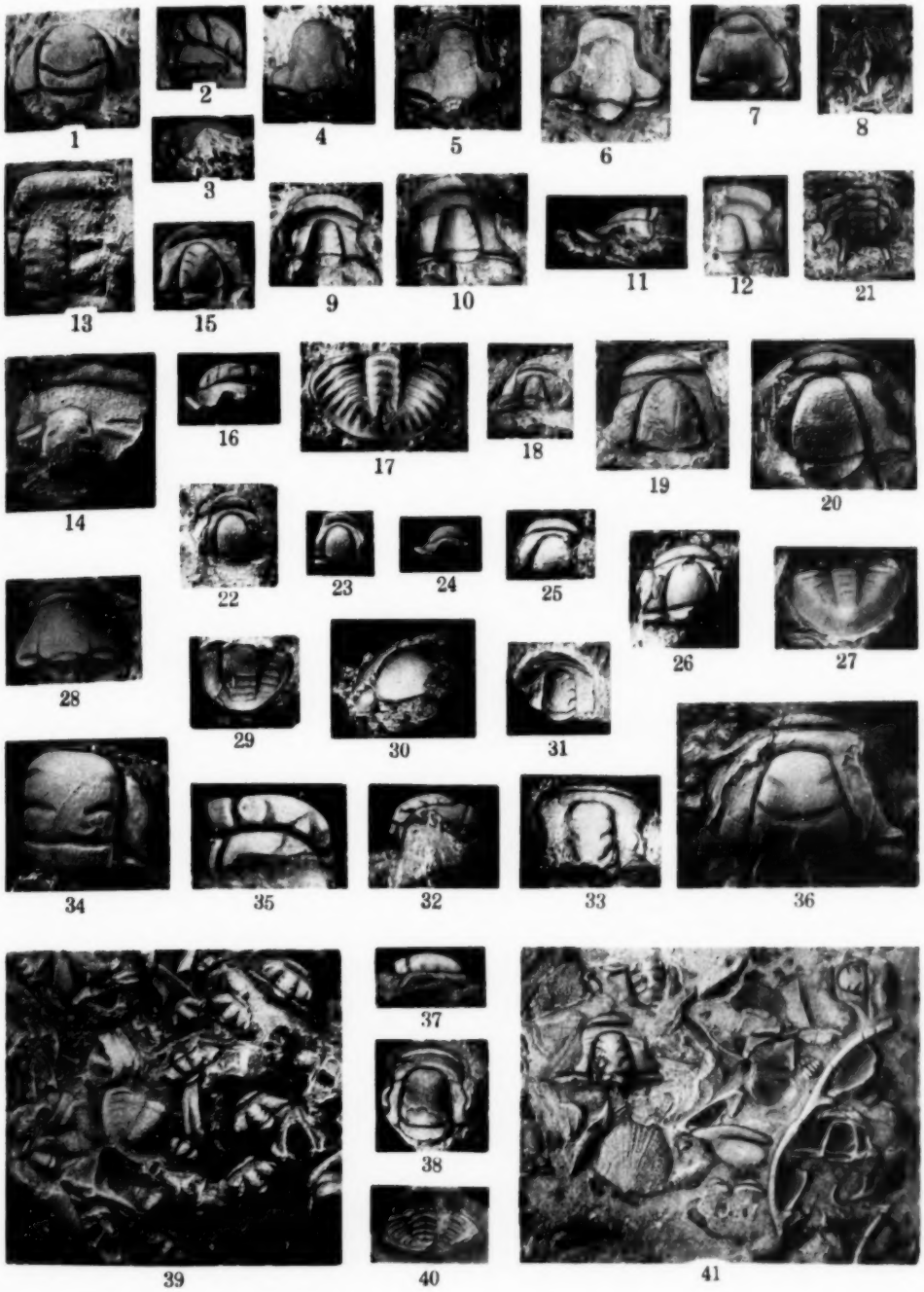
34, 35—*Dartonaspis knighti* Miller, n. gen. and sp., holotype, dorsal and side views of cranidium; Gallatin formation, Bull Lake Creek, Fremont County, Wyoming. (p. 29)

36—*Elvinia roemeri* (Shumard), dorsal view of cranidium, Gallatin formation, South Fork of Teton Canyon Creek, Teton County, Wyoming. (p. 30)

37, 38—*Dunderbergia? declivita* Miller, n. sp., holotype cranidium, dorsal and side views; same horizon and locality as fig. *30*. (p. 30)

39—*Bolaspis? resseri* Miller, n. sp., slab, ×2, showing a number of cranidia (the pygidium is *Glyphaspis* sp.); Gros Ventre formation, Death Canyon member, South Fork of Teton Canyon Creek, Teton County, Wyoming. (p. 27)

40, 41—*Taenicephalus cordillerensis* Miller, n. sp., Gallatin formation, Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming. *41*, Slab showing several cranidia and free cheeks, and *Billingsella coloradoensis* (Shumard). *40*, An associated pygidium. (p. 33)



Miller, Cambrian Trilobites

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glabellar area. Occipital furrow narrow but distinct. Palpebral lobes relatively large, length slightly less than one-half the length of the glabella; eye-lines absent. Free cheeks, thorax, and pygidium unknown. A few coarse granules scattered over upper part of glabella and occasionally on the border and rim.

Observations and comparisons.—Accurate description of the occipital ring and postero-lateral limbs must await the discovery of better material, since these features are broken off in all cranidia found. *B. globosa* is readily distinguished from all other species of *Blountia* by its globose, elevated glabella. It appears to be more closely related to *B. anser* Walcott than to any other described species.

Formation and locality.—Gallatin formation, glauconitic limestones at the base of the Du Noir member; Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming.

Syntypes.—Columbia Univ. 12,620, 12,621.

BLOUNTIA DUNOIRENSIS Miller, n. sp.

Plate 8, figures 25–27

Cranidium moderately convex, characterized by deeply impressed furrows and narrow, depressed preglabellar area. Facial suture directed outward and backward behind the eyes, delimiting moderate postero-lateral limbs; diverging anterior to the eyes; intramarginal, possibly to the center. Glabella rounded-conical in outline, moderately convex, not marked by glabellar furrows. Preglabellar area a narrow ridge, somewhat depressed below rim, barely separating the glabella from the deep frontal furrow. Rim convex, about three times as wide in the middle as the preglabellar area, tapering toward the anterior angles. Circum-glabellar and occipital furrows strong; occipital ring three or four times as wide as the furrow.

Associated pygidium semioval in outline; axis convex, tapering, extending to the broad, flattened rim; marked by about four weak furrows barely traceable on the pleural lobes.

Surface smooth.

Observations.—The palpebral lobes are badly damaged and for the most part broken off in all specimens collected. They appear to have been rather large, somewhat less than one-half as long as the glabella. This species more nearly resembles *B. amage* Walcott than any other described species; it differs in having a broader rim and narrower preglabellar area.

Formation and locality.—Gallatin formation, glauconitic limestones at the base of the Du Noir member; Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming.

Syntypes.—Columbia Univ. 12,617, 12,618.

Genus BOLASPIS Resser, 1935

BOLASPIS? RESSERI Miller, n. sp.

Plate 8, figure 39

Cranidium moderately convex, small, relatively broad; mature specimens 5 mm. wide across the base, 2.5 mm. long. Facial suture converging slightly anterior to the eyes, flaring widely posterior to the eyes, delimiting an extremely broad base with narrow posterior limbs. Glabella moderately convex, sides tapering anteriorly, apparently marked by two pairs of short, transverse furrows which, on weathering, tend to develop into elongate pits and depressions. Frontal limb strongly concave just anterior to the glabella and eye-lines; rim strongly upturned, convex, about half as wide as the pre-glabellar area, tapering slightly and becoming less elevated toward the anterior angles. Fixed cheeks relatively broad, strongly convex, tumid. Palpebral lobes prominent, strongly elevated, about one-third as long as glabella exclusive of the occipital ring; position of eye-lines marked by boundary between concave frontal limb and tumid portion of fixed cheeks. Circum-glabellar furrow wide, deeply impressed along sides, merging anteriorly with concave frontal limb.

Occipital furrow deeply impressed; occipital ring convex, about three times as wide as the furrow. Free cheeks, pygidium, and thorax unknown. Coarse, irregularly shaped granules are observable on the surface of well-preserved specimens.

Comparisons.—Although this species may represent a new genus, it is believed advisable to refer it to *Bolaspis* because of the scanty material available for study. *B.? resseri* differs from all described species of *Bolaspis* in having a strongly concave frontal limb, in the absence of a boss on the preglabellar area, and in the absence of the occipital spine.

Formation and locality.—Type, Gros Ventre formation, talus from Death Canyon member, 100 feet below the top; South Fork, Teton Canyon Creek, Teton County, Wyoming. Death Canyon, member 75 feet below the top; Gros Ventre Mountains, 1 mile east of Cache Creek and 9 miles southeast of Jackson, Teton County, Wyoming.

Holotype.—Columbia Univ. 12,608.

Genus BRACHYASPIS Miller, n. gen.

Genotype: *Brachyaspis rhynchina* Miller.

Brachyaspis does not appear closely related to any described genus, though comparable to *Plethometopus* Ulrich, 1930, from which it differs in the stronger differentiation of the glabella, in being less convex, and particularly in that the frontal limb is strongly depressed anterior to the glabella.

BRACHYASPIS RHYNCHINA Miller, n. sp.

Plate 8, figure 7

Cranidium small, moderately convex, not deeply furrowed, with short, blunt posterior limbs. Facial suture obliquely truncating anterior angles, converging slightly anterior to eyes, curving posteriorly on nearing posterior margin. Glabella moderately convex, barely differentiated from fixed cheeks; glabellar furrows absent. Frontal limb broad, distinctly depressed just anterior to glabella, passing anteriorly into broadly convex, elevated rim. Eye-lines faint, arching forward; palpebral lobes small, poorly defined, opposite anterior end of glabella. Circum-glabellar furrow very faint; occipital furrow shallow, indefinitely defined, narrower and more deeply impressed in extension across posterior limbs. Occipital ring posteriorly elevated, about twice the width of the furrow, regularly curved on posterior. Surface smooth. Free cheeks, thorax, and pygidium unknown.

Formation and locality.—Gros Ventre formation, calcareous lenses in ferruginous shales 120 feet above the top of the Death Canyon member; Crow Creek Canyon, 3 miles north of Tipperary, Fremont County, Wyoming. This species is associated with *Crepicephalus? wyomingensis.*

Holotype.—Columbia Univ. 12,604.

BRACHYASPIS? sp.

Plate 8, figure 8

A number of fragmentary cranidia are associated with *B. rhynchina* and are similar to it in size, convexity, and in the faint differentiation of the glabella from the fixed cheeks. The cranidia differ from *B. rhynchina* mainly in the possession of flaring, pointed posterior limbs, in the absence of the transverse depression on the frontal limb, and in that the occipital ring is produced posteriorly into a triangular shield which may bear a short spine.

Formation and locality.—Same as for *B. rhynchina.*

Figured specimen.—Columbia Univ. 12,605.

Genus CEDARIA Walcott, 1924

CEDARIA aff. C. PROLIFICA Walcott

Plate 8, figure 18

Cedaria prolifica WALCOTT, *1924*, Smithsonian Misc. Coll. vol. 75, no. 2, p. 55, pl. 10, fig. 6; *1925, Idem*, vol. 75, no. 3, p. 79, pl. 17, figs. 18–21.

The glabella of the Wyoming specimen

is proportionately narrower and the border is more elevated than in typical *Cedaria prolifica*. Free cheeks, thorax, and pygidium unknown. Surface dotted with small granules.

Formation and locality.—Gallatin formation, glauconitic limestones at the base of the Du Noir member; Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming.

Hypotype.—Columbia Univ. 12,632.

Genus CREPICEPHALUS Owen, 1852

CREPICEPHALUS? WYOMINGENSIS Miller, n. sp.

Plate 8, figures 9–12

Cranidium broad at base, with wide, flaring frontal limb produced by the divergent course of the facial suture anterior to the eyes. Anterior angles rounded, facial suture apparently cutting frontal margins approximately in line with eyes. Glabella convex, sides rising at 40° to meet in a subangular arch along the crest; conical, rounded in front, marked by three pairs of short, barely discernable furrows. Frontal limb concave as a whole; preglabellar area slightly convex, separated by broad frontal furrow from the flattened, upturned rim. Eye-lines prominent; palpebral lobes strongly bowed outward, usually broken off. Middle of occipital ring about twice width of furrow, narrowing toward ends.

Free cheeks, pygidium, and thorax unknown.

Surface minutely granular. On exfoliated specimens a vertical system of venation lines is barely discernible on the brim anterior to the eye-lines.

Comparisons.—This species is tentatively referred to *Crepicephalus* because of the similarity of its cranidium to that of *C. coosensis* Walcott, which probably is not a *Crepicephalus*. The cranidium of the Wyoming species has the same general characteristics, but has relatively broader limbs, less prominent and less elevated palpebral lobes, and a broader and more deeply impressed frontal furrow than in *C. coosensis*. In *C. coosensis* the venation lines on the brim are prominent, whereas they are barely discernible in *Crepicephalus? wyomingensis*.

Formation and locality.—Gros Ventre formation, calcareous lenses in ferruginous shales 120 feet above the top of the Death Canyon member; Crow Creek Canyon, 3 miles north of Tipperary, Fremont County, Wyoming.

Syntypes.—Columbia Univ. 12,601–12,603.

Genus DARTONASPIS Miller, n. gen.

Genotype: *Dartonaspis knighti* Miller.

This genus is closely related to *Irvingella* Ulrich and Resser, 1924. The most notable difference is in the shape of the fixed cheeks, which in *Dartonaspis* are bowed outward anteriorly and constricted posteriorly, whereas in *Irvingella* the fixed cheeks are obliquely truncated anteriorly and strongly bowed posteriorly. In *Dartonaspis* the glabella expands regularly toward the front and the furrows do not unite across the glabella, whereas in all described species of *Irvingella* the glabella is semi-ovoid in outline and the posterior pair of furrows is united across the glabella. The description of the genotype completes the generic characters known at present.

The generic name is in recognition of the contributions of Dr. N. H. Darton to the stratigraphy of Wyoming.

DARTONASPIS KNIGHTI Miller, n. sp.

Plate 8, figures 34, 35

Cranidium strongly convex. Facial suture cutting transversely across the front just anterior to the glabella, swinging widely around the large palpebral lobes, constricting the fixed cheeks posteriorly, delimiting rather short posterior limbs. Glabella subquadrate in outline, expanding anteriorly, strongly convex; marked by two pairs of furrows; first pair very faint or absent; second pair strong, extending nearly to the glabellar crest but not uniting. Frontal limb consisting of a transverse, ridge-like border; rim absent. Occipital furrow strong, curving forward and widest in the middle,

slightly offset anteriorly from its extension across the posterior limbs; circumglabellar furrow deeply impressed, entire. Occipital ring wide, flattened. Free cheeks, thorax, and pygidium unknown. Surface smooth.

The specific name is in honor of Prof. S. H. Knight, State Geologist of Wyoming.

Formation and locality.—Gallatin formation, limestones 175 feet above the base; Bull Lake Creek, Fremont County, Wyoming. This species occurs 40 feet above the *Taenicephalus* beds of the Gallatin.

Holotype.—Columbia Univ. 12,626.

Genus DUNDERBERGIA Walcott, 1924

DUNDERBERGIA? DECLIVITA Miller, n. sp.

Plate 8, figures 37, 38

Cranidium characterized by small postero-lateral limbs and steeply inclined frontal limb. Glabella strongly and evenly convex, subconical, rounded anteriorly; glabellar furrows represented by two pairs of very faint, poorly defined depressions, anterior pair transverse, extending from base about half way to the crest of the glabella; posterior pair slightly longer, curved backward. Preglabellar area bulging slightly just anterior to circum-glabellar furrow, then inclining rapidly and merging into frontal furrow. Rim narrow, widening toward center owing to intramarginal course of facial suture. Fixed cheeks narrow, flattened, forming a nearly level platform along sides of glabella. Eye-lines present; palpebral lobes prominent, located opposite middle of glabella. Occipital ring flattened, about twice width of furrow.

Free cheeks, thorax, and pygidium unknown.

Minute granules dot the upper part of the glabella, becoming less numerous along the sides; rest of surface apparently smooth.

Comparisons.—Although *D. declivita* may represent a new genus, it has the same general characteristics as *D. nitida* (Hall and Whitfield), and because of the scanty material available for study it is believed advisable to refer the species to *Dunderbergia*. It differs from *D. nitida* in that the border is more steeply inclined from the glabella to the rim, not convex as in *D. nitida;* and in the flat, platform-like form of the cheeks bordering the sides of the glabella.

Formation and locality.—Gallatin formation, limestones 175 feet below the top; northwest quarter, T. 39 N., R. 92 W., Dry Creek, Fremont County, Wyoming. Closely related species or varieties occur in the *Elvinia* beds of the Gallatin in the Teton and Gros Ventre Mountains.

Holotype.—Columbia Univ. 12,630.

Genus ELVINIA Walcott, 1924

ELVINIA ROEMERI (Shumard), 1861

Plate 8, figure 36

Dikelocephalus roemeri SHUMARD, *1861*, Am. Jour. Sci., 2d. ser., vol. 32, p. 220.
Elvinia roemeri WALCOTT, *1924*, Smithsonian Misc. Coll., vol. 75, no. 2, p. 56, pl. 11, fig. 3; *1925, Idem*, vol. 75, no. 3, p. 88, pl. 17, figs. 9–13.

The Wyoming specimens, which are represented by numerous cranidia, free cheeks, and pygidia, appear to differ in no essential respect from the original Texas specimens.

Formation and locality.—Gallatin formation, limestones 100 to 115 feet above the base; various localities in the Teton, Gros Ventre, and Wind River Mountains, Wyoming.

Hypotype.—Columbia Univ. 12,631.

Genus GLYPHASPIS Poulsen, 1927

GLYPHASPIS cf. G. PERCONCAVA Poulsen, 1927

Plate 8, figure 17

This form is represented in the Wyoming collections by several fine pygidia. The segments on the axis and border of the Wyoming specimens are a little narrower than those shown by plaster casts of the holotype of *G. perconcava.*

Formation and locality.—Gros Ventre formation, black limestones in the upper 15 feet of the Death Canyon member,

South Fork, Teton Canyon Creek, Teton County, Wyoming.

Hypotype.—Columbia Univ. 12,609.

Genus IRVINGELLA Ulrich and Resser, 1924

IRVINGELLA GIBBA Miller, n. sp.

Plate 8, figures 1, 2

Cranidium strongly convex. Facial suture cutting across front in a straight, transverse line just anterior to glabella, cutting obliquely backward from anterior angles, then swinging widely around the large palpebral lobes, delimiting broad, tumid fixed cheeks. Glabella subovoid in outline, gibbous, rising abruptly from deep circum-glabellar furrow; glabella marked by three pairs of furrows; anterior pair short, narrow, probably not visible on unexfoliated specimens; second pair stronger; posterior pair deep, broad, curving backward and uniting across glabella. Frontal limb consisting of a narrow, raised border; rim absent. Occipital furrow deep, about half as wide as flattened ring. Free cheeks, thorax, and pygidium unknown. Surface smooth.

Comparisons.—The glabella of *I. gibba* is much more convex than the glabella of *I. major* Ulrich and Resser, rising more abruptly and to a greater height above the dorsal furrow, especially toward the front.

Formation and locality.—Type, Gallatin formation, limestones 130 feet above the base; South Fork, Teton Canyon Creek, Teton County, Wyoming. Limestones 115 feet above the base, Warm Springs Creek, 2 miles west of Du Noir, Wyoming; talus limestone slabs at 125 feet above the base, North Fork, Popo Agie River, Fremont County, Wyoming. This species occurs above the *Elvinia* beds and below the *Taenicephalus* beds of the Gallatin formation in the Teton and Wind River Mountains, the distance above the *Elvinia* beds being about 15 feet.

Holotype.—Columbia Univ. 12,625.

Genus KINGSTONIA Walcott, 1924

KINGSTONIA SUBLETTENSIS Miller, n. sp.

Plate 8, figures 28, 29

Cranidium small, convex, nearly smooth, scarcely differentiated into free cheeks and glabella, evenly arched across the base. Facial suture curving out and back behind eyes, delimiting rather short postero-lateral limbs, converging very slightly anterior to eyes, rounding the anterior angles. Glabella scarcely defined; circum-glabellar furrow converging very slightly toward anterior, barely discernible along rounded front of glabella. Border practically continuous with glabella, convex, inclining to the narrow rim. Glabellar furrows absent; occipital furrow very weak, wider and somewhat stronger in its extensions across the postero-lateral limbs.

Pygidium subtriangular in outline, borderless, the convex sides rising abruptly above margin. Axis clearly defined anteriorly, tapering slightly posteriorly and fading out just before reaching the convex, steeply descending end of pygidium; axis marked by five or six indistinct furrows which in exfoliated specimens are more clearly defined and sometimes traceable on the pleural lobes.

Surface smooth except for rim, which is striated parallel to the frontal margin.

Comparisons.—The cranidium of this species is similar in general outline and convexity to that of *Kingstonia apion* Walcott, but differs in being broader and in having proportionately broader postero-lateral limbs; the rim of *K. sublettensis* is broader and more clearly set off by the furrow from the border area. The greatest difference between the two species is in the pygidium, which is subtriangular in *K. sublettensis*, but is more or less abruptly truncated in *K. apion*, without much convergence of the sides. The pygidium of *K. sublettensis* is similar in outline to that of *Tsinania canens* Walcott but differs in its greater convexity and in that the axis has fewer, less distinct segments and is much more

elevated above the rest of the shield, particularly toward the front.

Formation and locality.—Type, Gallatin formation, glauconitic limestones at the base of the Du Noir member; Clear Creek, 1 mile north of Green River Lakes, Sublette County, Wyoming. Basal limestones of the Du Noir member, Warm Springs Creek, Torry Creek, and Bull Lake Creek, all in the Wind River Mountains, Fremont County, Wyoming.

Holotype.—Columbia Univ. 12,615.

Genus KOCHASPIS Resser, 1935

KOCHASPIS? sp.
Plate 8, figures 13, 14

A genus related to *Kochaspis* and to *Inglefieldia* Poulsen, 1927 is represented in the Wyoming collections by several fragmentary cranidia. The genus appears similar to *Kochaspis* in most of the characters that are observable, differing in the outline of the glabella, which is subquadrate in the Wyoming specimens, not strongly tapering as in *Kochaspis*. *Inglefieldia* lacks the granulose surface of the Wyoming specimens.

The two specimens illustrated represent two varieties or possibly distinct species, since the specimen shown by fig. 14 has a swelling on the preglabellar area which is lacking in the other specimen.

Formation and locality.—Gros Ventre formation, thin-bedded limestones in the upper 20 feet of the Death Canyon member; Crow Creek Canyon, 3 miles north of Tipperary, Fremont County, Wyoming.

Figured specimens.—Columbia Univ. 12,633, 12,634.

Genus KYPHOCEPHALUS Miller, n. gen.

Genotype: *Kyphocephalus bridgerensis* Miller.

Kyphocephalus does not appear to be closely related to any described genus. The deeply furrowed glabella, broad free cheeks, and coarsely granulated surface are suggestive of *Eurekia* Walcott, 1924, but the flaring frontal limb with its wide, arched rim and narrow, transverse frontal furrow are distinct. The description of the genotype includes all the generic characters known at present.

KYPHOCEPHALUS BRIDGERENSIS Miller, n. sp.
Plate 8, figures 30–33

Cranidium strongly convex, arched or humped longitudinally. Facial suture flaring widely anterior to eyes, delimiting a frontal limb nearly as broad as the base of the cranidium; postero-lateral limbs proportionately small. Glabella elongate, rounded in front, strongly convex; marked by three pairs of furrows, posterior pair sharply curving backward, much more deeply impressed than the others. Frontal limb convex, strongly arched transversely. Rim convex, elevated slightly just anterior to furrow, then dropping in a rapidly declining arch to margin; rim nearly twice as wide as the convex border, tapering near the anterior angles. Border and rim closely appressed, reducing frontal furrow to a suture-like, transverse line. Eye-lines elevated; palpebral lobes medium in size, located just posterior to mid-point of cranidium. Occipital and circumglabellar furrows deeply impressed, entire. Occipital ring about three times the width of the furrow. Free cheeks known only from fragments; broad, tumid, bounded by a wide, convex rim. Thorax and pygidium unknown. Surface dotted with coarse, elevated granules with smaller granules in the interspaces.

Formation and locality.—Gallatin formation, limestones 175 feet below the top; northwest quarter, T. 39 N., R. 92 W., Dry Creek, Fremont County, Wyoming. This species is associated with *Dunderbergia? declivita*.

Types.—Holotype, Columbia Univ. 12,627; paratypes, Columbia Univ. 12,628, 12,629.

Genus MARJUMIA Walcott, 1916

Two species from the Gros Ventre formation probably represent a new genus, but are provisionally referred to *Mar-*

jumia until material for study is more complete. Both species are characterized by convex cranidia with strong circumglabellar, frontal, and occipital furrows and high, subangularly-crested glabella marked by three pairs of furrows, the anterior pair faint, nearly transverse, the posterior pairs deflected backward. Both species differ from known species of *Marjumia* in possessing a very narrow, relatively depressed preglabellar area and in that the surface is granulose, not pitted.

MARJUMIA? TETONENSIS Miller, n. sp.

Plate 8, figures 19–21

Cranidium convex, moderately broad at the base. Facial suture diverging anterior to the eyes, rounding the anterior angles. Glabella strongly convex, sides meeting along the elevated crest in a nearly angular arch; glabella marked by three pairs of shallow furrows; anterior pair barely discernible, nearly transverse posterior pairs stronger, oblique. Preglabellar area depressed, reduced to a low, narrow ridge barely separating the deeply-impressed circum-glabellar and frontal furrows. Rim convex, tapering laterally. Palpebral lobes moderately large, usually broken off; eye-lines elevated. Occipital ring convex, about three times as wide as the deeply-impressed furrow, tapering at lateral extremities. Free cheeks and thorax unknown. Associated pygidium has four segments, each of which is produced into a pair of slender border spines. Surface of cranidium granulose; pygidium apparently smooth.

Observations and comparisons.—It is questionable whether the associated pygidium belongs with the cranidium described above, particularly since the cranidium is granulose and the pygidium appears to be smooth. The pygidium seems to differ in no essential respect from the pygidium of *Marjumia typa* Walcott.

Formation and locality.—Type, Gros Ventre formation, talus limestone blocks from the Death Canyon member 100 feet below the top; South Fork of Teton Canyon Creek, Teton County, Wyoming. Death Canyon member 75 feet below the top; Gros Ventre Mountains, 1 mile east of Cache Creek and about 9 miles southeast of Jackson, Teton County, Wyoming. This species is associated with *Bolaspis? resseri.*

Syntypes.—Columbia Univ. 12,607, 12,610.

MARJUMIA? TIPPERARYENSIS Miller, n. sp.

Plate 8, figures 15, 16

Cranidium convex; facial suture diverging anterior and posterior to eyes. Glabella strongly elevated, subangularly-crested; glabella marked by three pairs of furrows, anterior pair faint, nearly transverse, second pair oblique, posterior pair deeply impressed, sharply deflected backward. Preglabellar area slightly less than the width of the flattened-convex rim. Palpebral lobes broken off, evidently medium in size; eye-lines elevated. Frontal, circum-glabellar, and occipital furrows deeply impressed. Occipital ring flattened-convex, about twice as wide as the furrow. Free cheeks, thorax, and pygidium unknown. Surface granulose.

Comparisons.—The glabella of this species is more elevated and more deeply furrowed than in *Marjumia? tetonensis*, the preglabellar area is wider, and the brim and occipital ring are narrower and less convex.

Formation and locality.—Gros Ventre formation, calcareous lenses in ferruginous shales 120 feet above the Death Canyon member; Crow Creek Canyon, 3 miles north of Tipperary, Fremont County, Wyoming. This species is associated with *Crepicephalus? wyomingensis.*

Holotype.—Columbia Univ. 12,606.

Genus TAENICEPHALUS Ulrich and Resser, 1924

TAENICEPHALUS CORDILLERENSIS Miller, n. sp.

Plate 8, figures 40, 41

Cranidium roughly triangular in outline. Facial suture flaring widely poste-

rior to eyes, giving a wide base, diverging slightly anterior to eyes, intramarginal inside the rim. Glabella moderately convex, rounded-conical, marked by three pairs of furrows directed obliquely backward. Posterior pair of furrows longer and more deeply impressed than others but not uniting across glabella; anterior pair, in some specimens, very faint or absent. Preglabellar area raised into a low, transverse ridge separated from the triangular, arched rim by the deep frontal furrow. Fixed cheeks raised just posterior to the prominent eye-lines into low, node-like elevations which are more pronounced in some specimens than in others. Palpebral lobes not prominent, opposite the second pair of glabellar furrows. Occipital ring about twice the width of the furrow, somewhat elevated in the center, in some specimens showing a tendency to develop a node. Free cheeks and pygidium known only from fragments, apparently similar to those of *T. shumardi* (Hall).

Surface smooth, although well-preserved specimens show striations on the brim anterior to the eye-lines. These striations, under the microscope, are resolved into a system of reticulating ridglets forming a pattern trending predominately at right angles to the eye-lines and circum-glabellar furrow.

Comparisons.—The cranidium of this species is similar to that of *T. shumardi* (Hall) but differs in being proportionately broader. The glabella of *T. cordillerensis* is more rounded and less conical, not squarely truncate in the front as in *T. shumardi*.

Formation and locality.—Type, Gallatin formation, limestones 135 feet above the base; Warm Springs Creek, 2 miles west of Du Noir, Fremont County, Wyoming. Limestones from 105 to 130 feet above the base, at various localities in the Wind River and Owl Creek Mountains, Fremont County, Wyoming. This species occurs 20–45 feet above the *Elvinia* beds of the Gallatin in the Wind River Mountains.

Holotype.—Columbia Univ. 12,622.

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NEW TRILOBITE GENERA FROM THE BONNETERRE DOLOMITE (UPPER CAMBRIAN) OF MISSOURI

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Five new trilobite genera of the early Late Cambrian fauna in the basal beds of the Bonneterre dolomite are described. *Crepicephalus* Owen is restricted, and the valid species of the new genus *Paracrepicephalus* are listed. Two new families, one opisthoparian and the other proparian, are established.

This paper presents the descriptions of two new families and five new genera of trilobites recognized during a recent study of abundant well preserved fossils from the lower 50 feet of the Bonneterre dolomite of southeastern Missouri. This fossiliferous limestone zone, averaging 10 feet in thickness, has yielded a fauna of 63 species, including 12 brachiopods; 41 trilobites, of which 24 are new; pteropods; crinoid and merostome fragments. The fauna is representative of the *Cedaria* zone of the early Late Cambrian.

The fauna contains the following described species

Echinodermata
  Cystoid plates
Molluscoidea
  Paterina stissingensis (Dwight)
  Iphidella pannula maladensis (Walcott)
  Obolus matinalis Walcott
  Obolus sinoe Walcott
  Lingulella perattenuata (Walcott)
  Dicellomus appalachia Walcott
  Dicellomus politus (Hall)
  Acrotreta ulrichi Walcott
  Linnarssonella transversa Walcott
Mollusca
  Hyolithes primordialis (Hall)
Arthropoda
  Paracrepicephalus comus (Walcott)
  Paracrepicephalus texanus (Shumard)
  Paracrepicephalus walcotti Lochman, **n. sp.**
  Coosella prolifica Lochman, n. gen. and sp.
  Genevievella neunia Lochman, n. gen. and sp.
  Blountia alethes Walcott
  Blountia arion (Walcott)
  Bonneterrina prima Lochman, n. gen. and sp.
  Lonchocephalus aff. *L. appalachia* Walcott
  Menomonia calymenoides (Whitfield)
  Millardia avitas Walcott
  Norwoodia quadrata (Whitfield)
  Norwoodia saffordi Walcott
  Norwoodia tenera Walcott
  Avonina bizarria Lochman, n. gen. and sp.

The dominant opisthoparian genus of the faunal assemblage is the new genus *Paracrepicephalus*. When Walcott compiled the species of *Crepicephalus* known in 1916 (1), he recognized two distinct groups of species within the genus, but, pleading lack of sufficient material, he did not make a generic separation. Now, however, the presence in the Bonneterre material of eight species assignable to Walcott's "*Crepicephalus texanus* group," all abundantly represented by well preserved specimens, completely validates the separation of the old genus *Crepicephalus* into *Crepicephalus* s.s. and *Paracrepicephalus*. *Crepicephalus* s.s., is characterized by a cranidium with a narrow transverse furrow and a narrow frontal border and a trans-

verse pygidium with a pair of spines extending from the pleural lobes along each side of a marginal border. *Paracrepicephalus* is characterized by a cranidium with a prominent frontal furrow marked by three pits, and a massive, nearly square pygidium with two long spines extending out from the pleural lobes on each side above the postero-lateral margin.

The following are recognized as valid species of *Paracrepicephalus:*

P. comus (Walcott)
P. coria (Walcott); lectotype, U. S. Nat. Mus. 61,689
P. danace (Walcott)
P. elongatus (Walcott)
P texanus (Shumard)
P. tripunctatus (Whitfield)
P. tripunctatus magnispinus (Walcott)
P. tumidus (Walcott)
P. walcotti Lochman, n. sp.; holotype, U. S. Nat. Mus. 61,655 (2)

Five other new species of this genus occur in the Bonneterre fauna.

The species described by Walcott as *Crepicephalus thoosa* is not valid. It is synonymous with *P. texanus*, as the holotype, U. S. Nat. Mus. 61,654, is identical with *P. texanus*.

These two related genera, *Crepicephalus* and *Paracrepicephalus*, have been placed in a new family, the Crepicephalidae, as neither is in any way related to the Ceratopygidae, to which the old genus *Crepicephalus* had been assigned.

Of the other new genera described in this paper, *Coosella* is known from several more species occurring in faunas of similar age in other parts of the United States, and *Genevievella* is known from three Bonneterre species. *Bonneterrina* and the small proparian genus *Avonina* are known only from the one species of each occurring in the Bonneterre fauna.

SYSTEMATIC DESCRIPTIONS

Order Opisthoparia Beecher
Family Crepicephalidae Lochman, n. fam.

Opisthoparia of medium size with subequal cephalon and pygidium; cranidium with convex conical glabella, well developed frontal limb and frontal border separated by a transverse furrow, and medium-sized eyes; free cheeks terminating in long heavy genal spines; thorax averaging twelve segments, the axial lobe convex and relatively narrow, the pleural lobes broad and flat near the axis, but arching downward and backward to the falcate terminations of the segments; pygidium with axial and pleural lobes of nearly the same width, marked by three or more furrows, and with two posteriorly directed spines formed by a bunching together and extension of the primitive falcate terminations of all the anchylosed segments of the two pleural lobes.

This family contains two genera, *Crepicephalus* Owen and *Paracrepicephalus* Lochman, n. gen., which had been placed in the Ceratopygidae because of the presence of two pygidial spines. However, not only are the cephala of the two families totally dissimilar in structure, but the origin and position of the pygidial spines are radically different.

Genus ~~Paracrepicephalus Lochman~~, Tricrepicephalus Kobayashi n. gen.

General form of dorsal shield broadly oval; axial lobe convex, half as wide as the pleural lobe. Cephalon broad, transversely semicircular, with a well-defined border and marginal furrow. Cranidium with prominent, conical glabella broadly

rounded in front and marked by three pairs of short glabellar furrows; occipital ring of medium width, convex, with or without an occipital spine; occipital furrow broad, rounded and narrowing at each end; dorsal furrow deeply impressed around the glabella. Fixed cheeks relatively narrow and convex; palpebral lobes of medium size, equalling one-third the length of the cranidium on the line of the facial suture; ocular ridge narrow, extending diagonally across the fixed cheeks to the dorsal furrow; fixed cheeks merging forward into the frontal limb; a well-defined transverse furrow marked by three rounded or transversely elongate pits; frontal limb and frontal border varying in width, convexity, and direction. Postero-lateral limbs of medium length and width, with a broad shallow intramarginal furrow. Free cheeks large, with a prominent marginal furrow, and long heavy posteriorly directed genal spines. Facial suture cutting the anterior margin on a line with the palpebral lobe and curving backward to the transverse furrow; running thence diagonally inward to the palpebral lobe, around which it curves; then passing outward and backward in a smooth curve to cut the posterior margin well within the genal angle.

Thoracic segments variable in number, averaging twelve; axial lobe convex, relatively narrow; pleural lobes broad, flattened for about one-half their width from the axis, then arching downward and backward; pleural furrows nearly as wide as the segment for one-third of its length and then narrowing and disappearing before reaching the falcate termination.

Pygidium convex, small and massive with two prominent hollow pleural spines; axial lobe broad and convex, extending three-fourths the length of the pygidium and divided by narrow furrows into three segments and a terminal section; dorsal furrow narrow, outlining the axial lobe; pleural lobes convex, dropping on the outside vertically to the margin, and divided by shallow, backward curving furrows into four segments; posteriorly directed spines originating in a strong base which merges into the side of the pleural lobes in such a manner as to give the impression that they were formed by the continuation outward and backward of the anchylosed segments of the pygidium; shape and curvature of the spines variable.

Outer surface of the test covered with granules of varying size.

Genotype: *Paracrepicephalus texanus* (Shumard).

This genus contains a number of species which were formerly referred to *Crepicephalus*. The species *P. texanus* (Shumard), the genotype, was the first of this group to be described and is the best known.

PARACREPICEPHALUS TEXANUS (Shumard)

Plate 9, figures 27, 28, 30, 32

Arionellus (*Bathyurus*) *texanus* SHUMARD, *1861*, Am. Jour. Sci., ser. 2, vol. 32, p. 218.
Crepicephalus texanus (Shumard) WALCOTT, *1899*, U. S. Geol. Survey, Mon. 32, p. 460.—GRABAU and SHIMER, *1910*, North Am. Index Foss., vol. 2, p. 283.—WALCOTT, *1916*, Smith. Misc. Coll., vol. 64, no. 3, pp. 209–214.—BUTTS, *1926*, Ala. Geol. Survey, Sp. Rept. 14, pl. 8, figs. 10, 11.—BRIDGE, *1932*, Univ. Texas, Bull. 3232, pl. 2, figs. 22, 23.
Not *Crepicephalus texanus* WALCOTT, *1908*, Smith. Misc. Coll., vol. 53, pp. 177–178.

Original description:

Head large, approaching semicircular, wider than long; glabella somewhat regularly convex, conical, distinctly separated from the sides and front by a deep groove; neck furrow distinctly impressed on the sides and nearly obsolete in the middle; border in front of the glabella broad, occupying about one-third the entire length of the head, and marked posterior to the middle with a deep, and rather wide, transverse furrow, which is parallel with the front margin, and has three deep transverse pits; anterior to this furrow is a broad, smooth space sloping from the front margin to the furrow. A line drawn transversely across the middle of the glabella, if extended would pass nearly through to the center of the eyes. The facial suture passes forward from the inner anterior corner of the eye, nearly par-

allel with the axis of the body, until it reaches a point opposite the extremity of the furrow of the front margin, then obliquely forwards and inwards to the front edge; behind the eye it turns suddenly outwards and slightly backwards and cuts the posterior border near the genal angle.

Pygidium short and somewhat massive, subelliptical, axis approaching semicylindrical, elevated above the lateral lobes, as wide as one lateral lobe, and occupying about two-thirds the length of the pygidium; rings four, separated by deep furrows; posterior margin gently arched in the middle and armed on either side with a long, curved, diverging spine (about eight lines long); lateral lobes gently convex, segments indistinct.

Although Shumard's types were not illustrated and were later destroyed by fire, the species is so well known from Walcott's later work that its validity is recognized. The neoholotype checks perfectly with Shumard's description and

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EXPLANATION OF PLATE 9

All figures natural size except as otherwise noted. *M.S.M. loc.* refers to the register of localities in the Dept. of Geology, Missouri School of Mines, Rolla, Mo.; *U.S.N.M. loc.* refers to the register of localities in the United States National Museum. All specimens figured are in the U. S. National Museum.

FIGS. *1–3—Bonneterrina prima* Lochman, n. gen. and sp. *1, 3,* Dorsal and profile views of holotype, a large imperfect cranidium lacking the postero-lateral limbs and occipital spine, U.S. Nat. Mus. 91,855. *2,* Paratype, associated free cheek, complete except for the end of the genal spine, U.S. Nat. Mus. 91,856; Bonneterre dolomite, along east-west road 1.5 miles N. of Thurman (Ste. Genevieve County), 0.4 miles west of road fork, and a short distance east of Andrews Branch, SE. ¼ SE. ¼ sec. 5, T. 37 N., R. 6 E. (M.S.M. loc. 82. 23), St. Francois County, Missouri. (p. 42)

4–11—Coosella prolifica Lochman, n. gen. and sp. *4, 5,* Dorsal and profile views of holotype, a perfect cranidium, U.S. Nat. Mus. 91,857. *8, 9,* Same, ×4. *7,* Paratype, an associated free cheek, U.S. Nat. Mus. 91,859. *10,* Same ×4; Bonneterre dolomite, outcrop in bed of Saline Creek, 1.2 miles southeast of school house at Avon, in SE. ¼ SE. ¼ sec. 12, T. 35 N., R. 7 E., Ste. Genevieve County, Missouri (M.S.M. loc. 76.20, U.S.N.M. loc. 91-*i*). *6, 11,* Paratype, a pygidium, ×1 and ×4, U.S. Nat. Mus. 91,858; outcrop in road ditch near base of steep hill 1 mile west of Avon, in NW. ¼ SW. ¼ sec. 11, T. 35 N., R. 7 E. (M.S.M. loc. 76.21, ?U.S.N.M. loc. 91-*z*). (p. 39)

12–21—Genevievella neunia Lochman, n. gen. and sp. *12,* Holotype, a large and nearly perfect cranidium, U.S. Nat. Mus. 91,860. *19,* Same, ×4; *16,* Profile, ×4. 15, Paratype, a cranidium, U.S. Nat. Mus. 91,861. *13,* Same ×4. *14,* Profile, ×4. *17, 18,* Paratype, associated pygidium and counterpart, U.S. Nat. Mus. 91,862. *20, 21,* Same, ×4. Bonneterre dolomite, M.S.M. 76.20 (see *Coosella prolifica,* above). (p. 41)

22–26—Avonina bizarria Lochman, n. gen. and sp. *25,* Dorsal view of large cranidium, ×6, holotype, U.S. Nat. Mus. 91,863. *26,* Same, ×4. *22,* Paratype, dorsal view of average sized cranidium, ×6, U.S. Nat. Mus. 91,864. *23,* Same, ×4. *24,* Profile of same, ×4. Bonneterre dolomite, M.S.M. loc. 76.20 (see *Coosella prolifica,* above). (p. 43)

27, 28, 30, 32—Paracrepicephalus texanus (Shumard). *27,* Dorsal view of neoholotype, a nearly complete medium sized cranidium, U.S. Nat. Mus. 91,865. *32,* Dorsal view of neoparatype, a medium sized pygidium, the bent tip of the left spine is considered a pathologic feature, U.S. Nat. Mus. 91,866. *30,* Profile view of same. Cap Mountain formation, cranidium from the summit of Potatotop Hill, 6 miles northwest of Burnet, Burnet County, Texas (U.S.N.M. loc. 67-*a*); pygidium from road ditch, state highway 29, southwest side of Lion Mountain, about 9 miles northwest of Burnet (U.S.N.M. loc. 92-*u*). These two localities are on the same belt of outcrop and about 5 miles apart. Shumard's original locality on the head of Clear Creek is about midway between them. (p. 37)

29, 31, 33—Paracrepicephalus walcotti Lochman, n. sp. *29, 31,* Dorsal and profile views of holotype, a large imperfect cranidium selected from the paratypes of *C. thoosa,* and showing the pointed anterior margin which distinguishes it, U.S. Nat. Mus. 61,655. *33,* Wax squeeze made from the counterpart of the holotype showing more of the outline of the fixed cheeks. Limestones in the Nolichucky shale, 1.5 miles southeast of Morristown, Tennessee (U.S.N.M. loc. 119). (p. 39)

Lochman, Cambrian Trilobites

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comes from the same general locality as Shumard's specimens.

Neoholotype: Cranidium, U. S. Nat. Mus. 91,865, from lower part of the Cap Mountain formation, summit of Potatotop hill, 7 miles N.W. of Burnet, Burnet County, Texas (U.S.N.M. loc. 67-A).

Neoparatype: Pygidium, U. S. Nat. Mus. 91,866, from same horizon, on S.W. side of Lion Mountain about 9 miles N.W. of Burnet on the road to Llano, Burnet County, Texas (U.S.N.M. loc. 92-u).

These two localities are about five miles apart on an east-west line. Shumard's original locality on the head of Clear Creek is on the same belt of outcrop and is about midway between the two.

PARACREPICEPHALUS WALCOTTI Lochman, n. sp.

Plate 9, figures 29, 31, 33

Crepicephalus thoosa WALCOTT (part) *1916*, Smithsonian Misc. Coll., vol. 64, no. 3, pp. 214, 215, pl. 31, figs. 1*a*, 1*a'*.

The cranidium of this species is characterized by a wide, pointed frontal border, illustrated in Walcott's figures 1a, and 1a′, as well as by the elongate conical glabella and more thickly set surface granules cited by Walcott.

Holotype: Cranidium, U. S. Nat. Mus. 61,655, from limestones in the Nolichucky shale, 1.5 miles S.E. of Morristown, Tennessee (U.S.N.M. loc. 119).

Walcott's description of this locality places the strata in the Maryville limestone, but subsequent field work has shown that they belong to the Nolichucky shale.

Family ANOMOCARIDAE Poulsen

Genus COOSELLA Lochman, n. gen.

Cranidium square in outline with a short broadly conical glabella; three pairs of short shallow glabellar furrows, posterior pair strongest and directed inward and backward; occipital ring of medium width; occipital furrow narrow and well defined only at the sides; dorsal furrow narrow, clearly outlining the glabella. Fixed cheeks one-third the width of the glabella; palpebral lobes situated on the transverse median line of the cranidium; palpebral furrow narrow and shallow; ocular ridge crossing the fixed cheeks diagonally to the dorsal furrow; frontal limb and border forming the anterior fourth of the cranidium; transverse furrow narrow. Postero-lateral limbs short, of medium width and marked by a shallow intramarginal furrow. Free cheeks narrow, crescentiform; eyes medium-sized. Facial suture passing outward and downward from the anterior border in a long curve to the edge of the frontal limb, thence crossing it in an oblique line to the palpebral lobe around which it curves; then extending diagonally backward and outward to cut the postero-lateral margin well within the genal angle.

Thorax not known.

Pygidium medium-sized, wider than long, with a broad flat border, axial lobe short, same width as the pleural lobes; axial and pleural lobes divided by narrow shallow furrows into three or four segments; marginal border unmarked by segments and increasing in width posteriorly; the posterior margin incurved at the median axial line giving a bilobed appearance to the border.

Genotype: *Coosella prolifica* Lochman, n. sp.

This genus is closely related to *Coosia*, but differs from it in the presence of a transverse furrow on the cranidium and the broader proportions of the cranidium, as well as in the pronounced bilobed appearance of the marginal border of the pygidium.

Several undescribed species belonging to this genus are known from the Upper Cambrian of Wisconsin and Texas.

COOSELLA PROLIFICA Lochman, n. sp.

Plate 9, figures 4–11

Cranidium with a short, moderately convex glabella, bluntly rounded in front; glabellar furrows very faint on

outer surface but well defined on inner surface of test; occipital ring flat, widening slightly towards the median line. Fixed cheeks slightly convex; palpebral lobes equalling almost one-half the length of the glabella; ocular ridge narrow; frontal limb narrow, slightly convex; transverse furrow well defined; frontal border convex, same width as frontal limb; anterior margin evenly rounded. Postero-lateral limbs short. Fixed cheeks narrow, marginal border pointed anteriorly and expanded posteriorly into a rounded genal angle. Facial suture cutting the anterior margin on a line with the palpebral lobes.

All the outer surface of the cranidium, except part of the frontal border, thickly covered with small granules, which on the frontal limb are roughly arranged in rows radiating out from the dorsal furrow; the posterior portion of the frontal border granulated in several transverse rows, and the anterior half marked by three or four rows of narrow, interrupted transverse ridges.

Pygidium medium-sized; axial lobe one-half the length of pygidium, narrow and moderately convex; a narrow tapering extension of the axial lobe continuing posteriorly for a short distance on to the broad marginal border; axial lobe divided by shallow furrows into three segments and a terminal section; pleural lobes divided into three broad low segments.

Outer surface of pygidium covered with small granules scattered sparsely over the axial and pleural lobes and very thickly over the marginal border, along the edge of which they appear to be grouped in short irregular rows; inner surface minutely punctate; doublure marked with fine imbricating furrows which run roughly parallel to the outer margin.

Th's species occurs abundantly in the Bonneterre collections, and many associations of the cranidium and pygidium have been obtained. A considerable range in size among the specimens has been observed, from immature stages 2 mm. in length to adult forms of the following dimensions: Cranidium: 13 mm. long, 13 mm. wide; pygidium: 13 mm. long, 18 mm. wide.

Upper Cambrian, Bonneterre dolomite (*Cedaria* zone).

Types: Holotype, cranidium, U. S. Nat. Mus. 91,857; paratype, free cheek, U. S. Nat. Mus. 91,859; from outcrop in bed of Saline Creek, 1.2 miles S.E. of the schoolhouse at Avon, Ste. Genevieve County, Missouri. Paratype, pygidium, U. S. Nat. Mus. 91,858, from outcrop in road ditch near base of steep hill about one mile W. of Avon, Ste. Genevieve County, Missouri. The block of limestone containing the holotype contains a pygidium identical with the one figured, but not as well preserved.

Family LEIOSTEGIIDAE Bradley

Genus GENEVIEVELLA Lochman, n. gen.

Cranidium small and broad, with a prominent convex glabella; three pairs of faint glabellar furrows; occipital furrow broad and shallow; occipital ring of medium width; dorsal furrow completely outlining the glabella. Fixed cheeks one-half the width of the glabella, convex; palpebral lobes situated close to the transverse median line of the cranidium; ocular ridge extending diagonally across the fixed cheeks to the dorsal furrow; no clearly defined frontal limb; a shallow transverse furrow separating the fixed cheeks from the frontal border. Postero-lateral limbs of medium width, marked by a narrow intramarginal furrow. No free checks known. Facial suture cutting the anterior margin abruptly on a line with the dorsal furrow, extending backward in a smooth curve to the transverse furrow and then in a straight line to the palpebral lobe around which it curves; thence passing outward in a straight line and then backward in an even curve to cut the posterior margin within the genal angle.

Thorax not known.

Pygidium small, transverse; axial lobe strongly convex, extending nearly to the

posterior margin, and the same width as the pleural lobes which are flat and drop abruptly to the narrow flat marginal border; four to six segments present on the axial and pleural lobes.

Genotype: *Genevievella neunia* Lochman, n. sp.

This genus appears to be closely related to the Upper Cambrian genus *Chuangia*, of China.

GENEVIEVELLA NEUNIA Lochman, n. sp.

Plate 9, figures 12–21

Cranidium with a strongly convex, conical glabella, broadly rounded in front; the anterior two pairs of glabellar furrows short and straight, the posterior pair long and arcuate; occipital ring semicircular in shape and slightly convex; dorsal furrow broad, deeply impressed along the sides of the glabella, but wide and shallow around the front. Fixed cheeks strongly convex; palpebral lobes wide and prominent, flap-like in form and separated from the fixed cheeks by broad palpebral furrows; palpebral lobes situated just posterior to the transverse median line of the cranidium; ocular ridge wide; frontal border of medium width, slightly convex; anterior margin thickened and straight. Postero-lateral limbs elongate, expanding slightly in width toward the lateral margin; intramarginal furrow broadens and ends before reaching the end of the limb.

Pygidium small with greatest width along the transverse median line; axial lobe one-third the width of the pygidium, tapering posteriorly, and divided by narrow furrows into five segments and a terminal section; dorsal furrow narrow and shallow, extending along both sides of the axial lobe, but not encircling the posterior end which merges backward into the border; pleural lobes divided by broad shallow furrows into four broad, backward curving segments which continue out onto the border nearly to the margin; narrow pleural furrows present on the anterior pair of pleural segments.

Outer surface of the cranidium punctate and covered with a few large scattered granules. Surface of pygidium covered with granules of two sizes of which the larger are arranged in a definite pattern—a single row of four or less on the pleural segments, and a row of four, in two lateral pairs, on each axial segment.

This species is represented in the Bonneterre collections by a large number of specimens. The adult cranidium and pygidium have the following dimensions: Cranidium: 5 mm. long, 7 mm. wide across the palpebral lobes; pygidium: 3.5 mm. long, 6 mm. wide.

Upper Cambrian, Bonneterre dolomite (*Cedaria* zone).

Types: Holotype, cranidium, U.S. Nat. Mus. 91,860; paratypes, two cranidia, U. S. Nat. Mus. 91, 861, and pygidium, U. S. Nat. Mus. 91,862, from outcrop in the bed of Saline Creek, 1.2 miles southeast of the school house at Avon, Ste. Genevieve County, Missouri. The smaller paratype cranidium is not figured.

INCERTAE SEDIS

Genus BONNETERRINA Lochman, n. gen.

Cranidium square in outline with a moderately convex conical glabella; glabellar furrows very faint; occipital ring wide and flat, with a large occipital spine; occipital furrow very shallow; dorsal furrow wide and shallow, completely outlining the glabella. Fixed cheeks less than one-half the width of the glabella; palpebral lobes wide, situated on the transverse line through the posterior third of the cranidium; a narrow ocular ridge running diagonally across the fixed cheeks to the dorsal furrow; frontal limb separated from the frontal border by a narrow transverse furrow. Postero-lateral limbs narrow, with a narrow shallow intramarginal furrow. Free cheeks large and wide with long heavy genal spines. Facial suture cutting the anterior margin on a line with the palpebral lobe, passing in a curve to the transverse furrow, and thence diagonally inward to the palpebral

lobe around which it curves; then running outward and backward to cut the posterior margin well within the genal angle. Thorax not known. Pygidium not known.

Genotype: *Bonneterrina prima* Lochman, n. sp.

The general resemblance of the cephalon of this genus to that of *Idahoia* from the later Upper Cambrian suggests a close relationship between the two genera. The chief differences are the slightly wider fixed cheeks of *Bonneterrina*, the shorter frontal limb and border, and the absence of granulations along the transverse furrow.

BONNETERRINA PRIMA Lochman, n. sp.

Plate 9, figures 1–3

Cranidium large, with glabella tapering forward to a rounded anterior margin; a pair of posterior glabellar furrows present; a large median occipital spine extending upward and backward from the occipital ring; occipital furrow present only at each side of the base of the glabella. Fixed cheeks slightly convex; palpebral furrow wide and shallow; ocular ridge prominent, extending diagonally from the palpebral lobes to the antero-lateral corner of the glabella; frontal limb of medium width; the wide, flat frontal border sharply upturned; anterior margin smoothly rounded. Free cheeks large, with a wide marginal border, and well defined marginal furrow; eye at the inner angle; border with a short pointed anterior projection and a heavy genal spine.

The outer surface of the cephalon smooth except for the impression of the inner network of heavy venations radiating outward across the frontal limb and free cheeks from the eyes and ocular ridge.

This species is represented by seven cranidia, one an immature individual, and several free cheeks in collections from six different localities. The largest cranidium has the following dimensions: 29 mm. long, 30 mm. wide across the palpebral lobes.

Upper Cambrian, Bonneterre dolomite (*Cedaria* zone).

Types: Holotype, cranidium, U. S. Nat. Mus. 91,855; paratype, free cheek, U. S. Nat. Mus. 91,856; from outcrop along the east-west road 1.5 miles north of Thurman (Ste. Genevieve County), 0.4 miles west of road fork, and a short distance east of Andrews Branch. The locality is in St. Francois County, Mo.

Order PROPARIA Beecher

Family AVONINIDAE Lochman, n. fam.

Proparia of small size, with conical, extremely convex glabella; frontal limb absent; postero-lateral limbs terminating in short genal spines. Pygidium not known.

This family is proposed for a new genus and species of Proparia occurring in the Bonneterre. It appears to be most closely related to the small proparian family Raymondinidae (3) from the Point Levis conglomerate.

Genus AVONINA Lochman, n. gen.

Cranidium small, with a long, strongly convex glabella; presence of glabellar furrows doubtful; occipital furrow narrow; occipital ring of medium width, convex; dorsal furrow very narrow, faintly outlining the glabella. Fixed cheeks narrow; palpebral lobes small, crescentiform, situated even with the transverse median line of the glabella; no frontal limb; a narrow frontal border. Postero-lateral limbs of medium width, elongate, directed backward at the genal angles into short, pointed spines; intramarginal furrow narrow and shallow. Free cheeks not known. Facial suture cutting the anterior margin outside the center of the cranidium and extending backward in an even curve to the palpebral lobe around which it curves; then passing diagonally outward and backward in a straight line to the lateral mar-

gin which it cuts a short distance anterior to the genal angle. Thorax not known. Pygidium not known.

Genotype: *Avonina bizarria* Lochman, n. sp.

AVONINA BIZARRIA Lochman, n. sp.

Plate 9, figures 22–26

Cranidium small, average length 2 mm., width 2 mm.; glabellar sides nearly parallel with a slight expansion towards the rounded anterior portion; no trace of glabellar furrows; occipital furrow well defined; occipital ring slightly convex. Fixed cheeks, convex, merging forward into the rounded, narrow frontal border; anterior margin evenly rounded.

Outer surface of the test smooth.

This species is represented in the Bonneterre collections by fifteen specimens from three different localities. The dimensions given in the description are those of the largest cranidia found, and are regarded as approximately adult size.

The completeness of the Bonneterre material has enabled the author to show conclusively that these specimens belong to a new genus and species and are not immature stages of *Norwoodia*.

Upper Cambrian, Bonneterre dolomite (*Cedaria* zone).

Types: Holotype, cranidium, U. S. Nat. Mus. 91,863; paratypes, two cranidia, U. S. Nat. Mus. 91,864; from outcrop in bed of Saline Creek, 1.2 miles S. E. of school house at Avon, Ste. Genevieve County, Missouri. The smaller paratype is not figured.

REFERENCES

1. WALCOTT, C. D., Cambrian trilobites: *Smithsonian Misc. Coll.*, vol. 64, no. 3, p. 201, 1916.
2. *Idem*, pl. 31, figs. 1*a–a'*.
3. As the genus is *Raymondina*, the correct construction of the family name is Raymondinidae instead of Raymondidae, as given by Clarke.

Note: The manuscript of this paper was received by the editor of the Journal June 20, 1935.

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THREE NEW MIOCENE DOGS AND THEIR PHYLOGENY

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ABSTRACT

A new genus from the Miocene Rosebud formation in South Dakota and two new species from Miocene beds in Nebraska are described. The phylogeny of the dogs is considered in order to place the new forms in proper relationship to the others.

Dogs have abounded in America ever since the Oligocene; and though generally conservative in structure, they have modified their structure in each geological epoch. In this paper three new forms are described, and then the phylogenetic changes in the group are considered in order to determine concrete characters by which the new forms may be arranged in their phylogenetic relationships.

SYSTEMATIC DESCRIPTIONS

Genus MAMMACYON Loomis, n. gen.

Genotype: *Mammacyon obtusidens* Loomis.

The characters of this genus are those of the genotype, described below.

MAMMACYON OBTUSIDENS Loomis, n. sp.

Figure 1

Type: An individual of which the skull, axis, humerus, radius, ulna, two metacarpals, and other bones are preserved; Amherst Coll. Mus. 34–41. Found in the summer of 1934 in the lower Miocene Rosebud formation on Porcupine Creek, South Dakota, just above the concretionary layer, or about 100 feet above the base of the beds.

Skull (fig. 1) 268 mm. long, of the rather long low *Amphicyon* type; dental formula, $\frac{3\ 1\ 4\ 3}{}$, as in amphicyonids. In general outlines skull similar to *Daphaenodon*, but *Mammacyon* differs from all the *Daphaenus-Amphicyon* group in the peculiar character of the teeth—all cusps are blunt, low hillocks. Premolar 4 excessively short, its shearing edge, if such it may be called, at the highest angle with the long axis of the jaw of any member of this family; deuterocone largest of any seen on any true dog; shearing surface on inner side of this tooth rounded, could scarcely have functioned as a cutting blade. Molar 1 likewise so peculiar as to be entirely characteristic; in early dogs of this group, protocone and hypocone form a continuous crescent (*Daphaenus*); in later representatives the two cusps tend to differentiate, the protocone being the larger; in *Mammacyon* the crescent has swollen into a single large cusp (protocone) that fills entire basin of inner lobe of tooth: on inner side of tooth the typical cingulum surrounds this big cusp. Molar 2 similar to molar 1 but smaller. On premolars 2 and 3, protocone blunt; no accessory cusps or cingula.

Blunt cusps throughout, large deuterocone, short rounded shearing portion of upper carnassial, and single round protocone of upper molar 1 are all characters that distinguish the genus *Mammacyon*, the nearest related genus being *Daphaenodon*. The species *obtusidens* is characterized mostly by its size, but as the type is the only specimen yet known, other characters will probably prove to be of specific value.

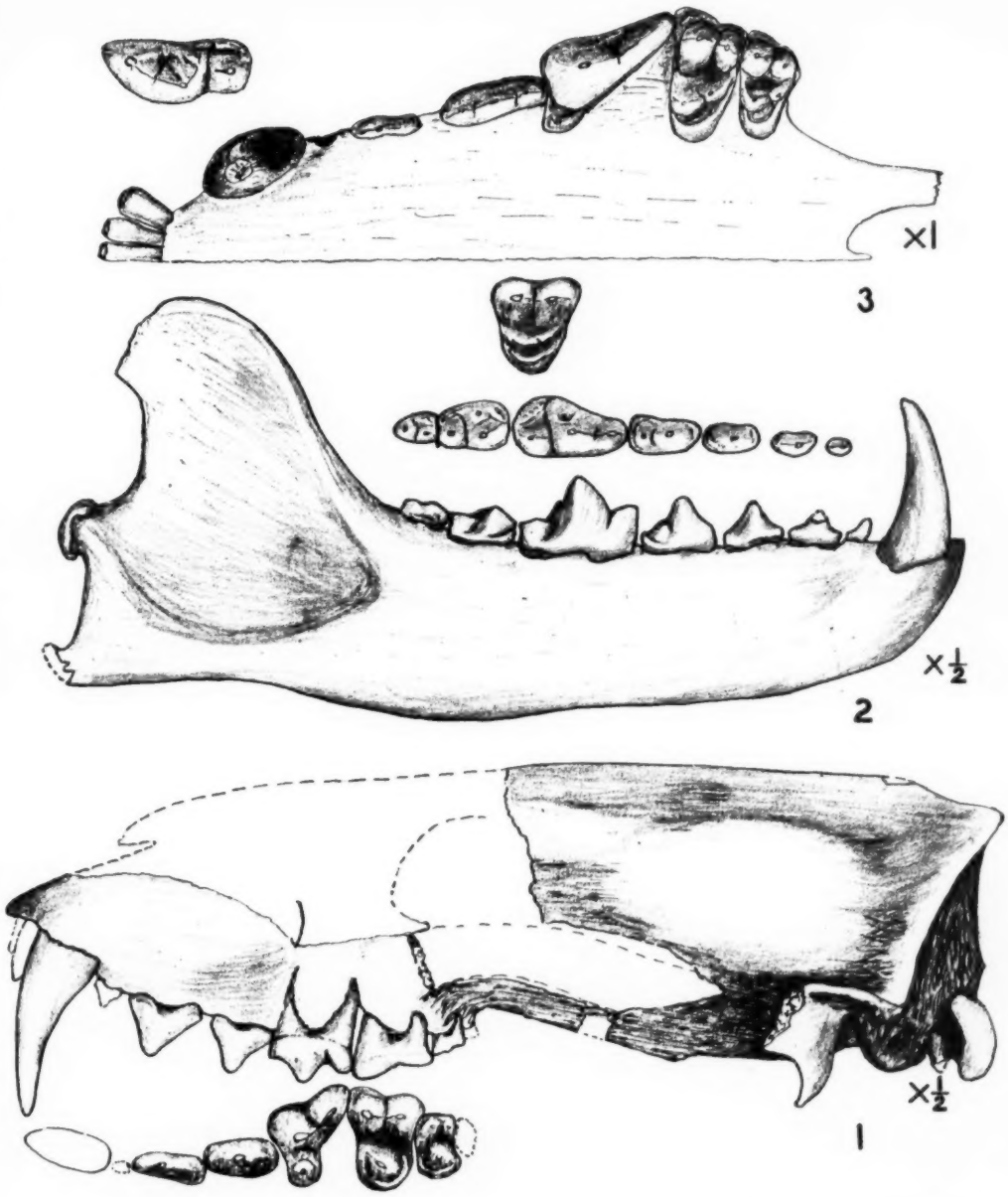

FIG. *1*—*Mammacyon obtusidens* Loomis, n. gen. and sp., the skull from the side and the upper dentition from below, ×½. (p. 45)

2—*Daphaenodon niobrarensis* Loomis, n. sp., lower jaw from the outside, the lower dentition from above, and upper molar 1, ×½. (p. 47)

3—*Temnocyon typicus* Loomis, n. sp., palatal view to show the upper dentition, and the lower carnassial, ×1. (p. 47)

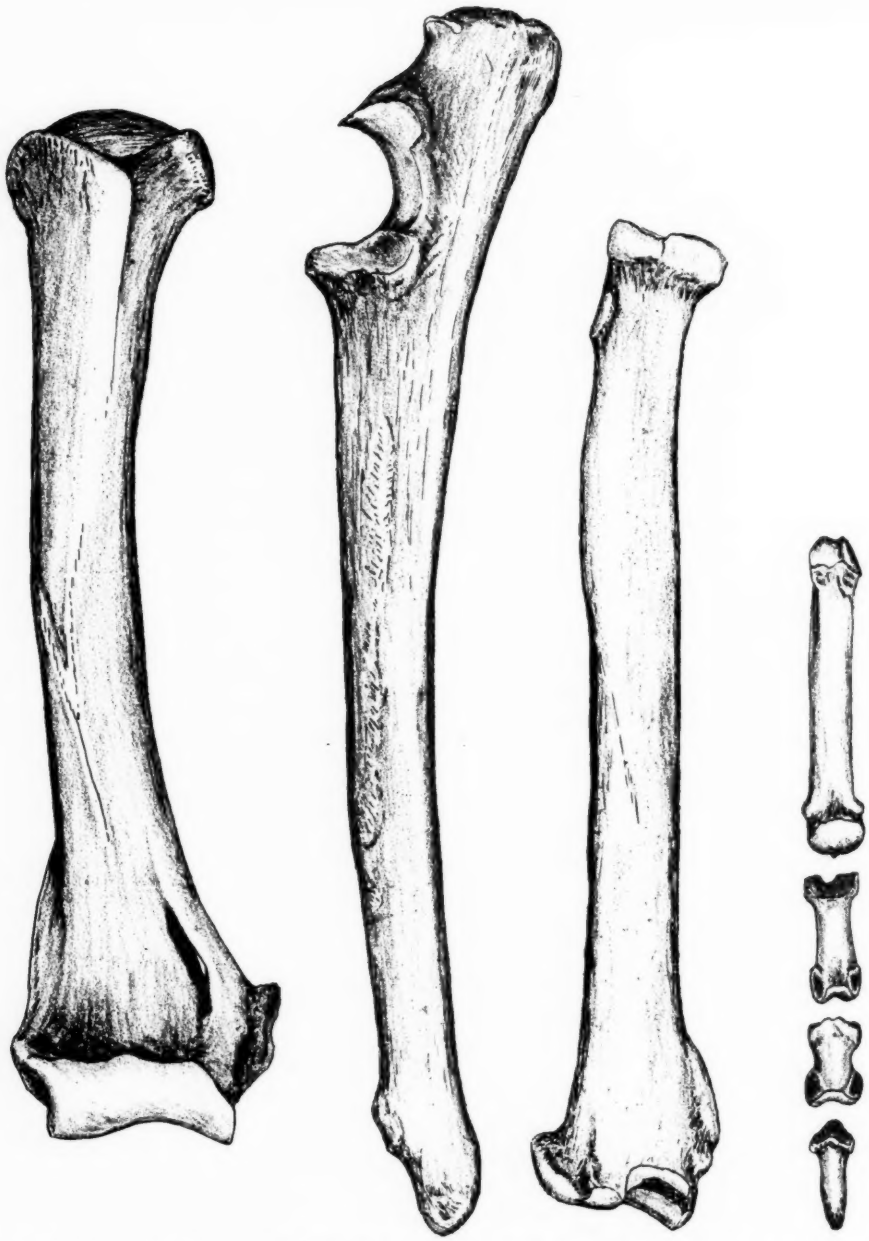

FIG. 4—*Daphaenodon niobrarensis* Loomis, n. sp., front leg bones and phalanges, ×½. (p. 47)

Most of the limb bones found belong to the front leg. They seem small for the size of the skull, but this is characteristic of amphicyonid dogs. The humerus has the large entepicondylar foramen distinctive of this group.

Cook (1) has described as *Daphaenodon periculosus* the lower jaw of a dog from the lower Miocene that may turn out to belong to *Mammacyon* when its upper jaw is known, for it too has remarkably low, blunt cusps on its teeth. I have seen no other dogs which could belong to the genus

DAPHAENODON NIOBRARENSIS
Loomis, n. sp.
Figures 2, 4

Type: A pair of lower jaws, upper molar 1, and both front legs practically complete to the last toes; Amherst Coll. Mus. 34–52. Found in 1934 in middle Miocene beds equivalent to the upper Harrison formation, near mouth of Antelope Creek, 12 miles southeast of Gordon, Nebraska. Associated with *Aletomeryx*.

A large dog, clearly belonging to *Daphaenodon*, best known by *D. superbus* Peterson (2) with which most of the comparisons will be made. *D. niobrarensis* is the largest species of *Daphaenodon* except *D. reinheimerensis*, based on a lower jaw with teeth mostly broken off. *D. periculorum* Cook, though only a little smaller is quite different. In *D. niobrarensis* premolars relatively wide; lower carnassial distinctive in that posterior portion is wide, and though the large hypoconid occupies most of heel, the entoconid is represented by a crenulated ridge, instead of two tiny cusps as in *D. superbus*. Lower molar 3 larger than in *D. superbus*, cusps well developed. Upper molar 1 distinctive in having no external cingulum; inner crescent shows less than usual tendency to divide into protocone and hypocone. A comparison of the length of the lower dentition will indicate the relative sizes of the dogs of this genus.

Distance from lower premolar 1 to molar 3

Daphaenodon niobrarensis	124 mm.
Daphaenodon superbus	95 mm.
Daphaenodon reinheimerensis	163 mm.

Except in size the limb bones of the front leg are very like those of *D. superbus;* the lengths of corresponding bones are proportional to the lengths of the respective jaws. Figure 4 has been carefully drawn to scale and the dimensions of these bones may be taken directly from the figure.

D. niobrarensis was found directly under the layer carrying *Aletomeryx*, the horizon of which has not been determined. The new species would not fix the horizon, but with it were found the lower jaws of a camel, *Oxydactylus longipes*, typical of the upper Harrison.

TEMNOCYON TYPICUS Loomis, n. sp.
Figure 3

Type: A skull imperfect in the brain case, part of the lower jaw, and some 8 vertebrae; Amherst Coll. Mus. 22–684. Found in the Miocene *Leptauchenia* beds 8 miles south of Mitchell, Nebraska.

In the genus *Temnocyon*, established for the John Day species, *T. altigens* Cope, the lower carnassial is trenchant, entoconid but a narrow ridge, upper carnassial long and sharp with a small deuterocone, no parastyle; inner portion of molar 1 tends to be reduced, bent toward the front. Several species assigned to the genus show very little resemblance beyond having the same dental formula. *T. typicus* is approximately the same in size as *T. altigens*, has similar premolars including carnassial; but upper molar 1 has inner portion less reduced, with less tendency to be excavated in front. The type of *T. altigens* has this inner portion of molar 1 partly broken, but protocone of *T. altigens* is larger, hypocone smaller than in *T. typicus*. In molar 2 of *T. altigens* inner lobe is more reduced, hypocone lacking; whereas in *T. typicus* inner lobe is large, hypocone moderately well developed.

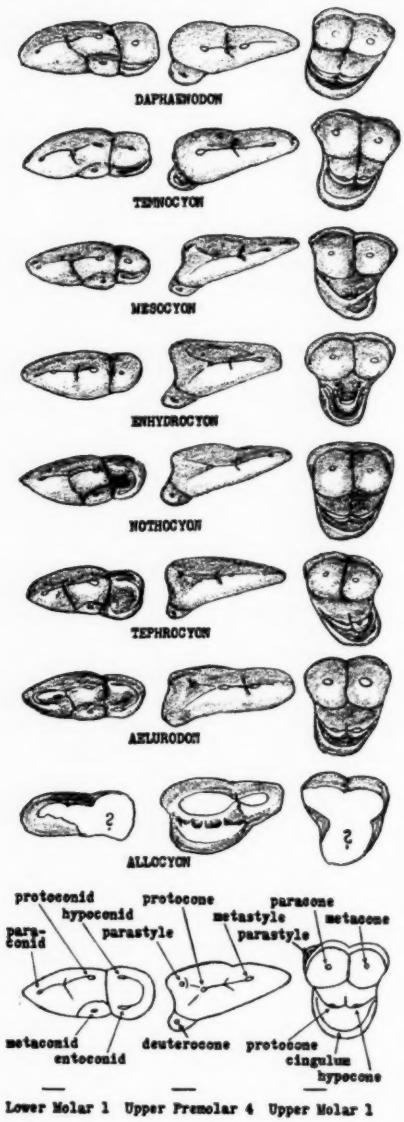

FIG. 5—The typical teeth of representatives of the eight phyla placed side by side for comparison. Below is a key to the nomenclature of the cusps, in accord with the tritubercular theory.

PHYLOGENETIC RELATIONSHIPS

In studying the Oligocene and Miocene genera of dogs I have found considerable confusion in assignment of species to the various genera; in general each genus is based on a different sort of feature. I have therefore tried to make a comparison of the genera and to find distinguishing features of the same sort for all of them, features which could be used even with incomplete material. I have found that the best comparative characters were in the carnassial teeth, and especially in molar 1 of the upper dentition. Matthew (3) in making his phylogenetic tree used the heel of the lower carnassial as a basis for division of all the dogs into two groups. The basin-like heel probably is the primitive condition, the basin being surrounded by a rim, on which there is usually a hypoconulid and entoconid developed. The dogs with a trenchant heel on this tooth acquire it by the hypoconulid enlarging and filling the basin, while the entoconid remains small and may even disappear entirely. This tooth is most useful as a primary criterion. Second, the upper carnassial may be long or short, may have the shearing edge well or feebly developed, may have a large or small or no deuterocone, and may have the parastyle developed. Finally, upper molar 1 is primarily a broad tooth with the paracone and the metacone well developed on the outer side, whereas the inner portion of the tooth is a broad lobe with two crescent-like ridges. The inner of these two crescents may be simple, more often is divided to make a protocone and hypocone; or one or the other may dominate. The outer crescent is

typically a cingulum around the inner margin, but it may be reduced either in front or behind. Finally the whole inner lobe of the tooth may be reduced in front, or behind, or both. Using these characters, but not forgetting that there are also skeletal characters and differences in the dental formulae, I recognize eight groups of Oligocene and Miocene dogs, each group being in the nature of a phylogenetic line. In the later groups there may be perhaps some other phyla, but most of the later genera seem to be derivatives of the earlier forms, as would be expected. The basis of each of these groups is shown in figure 5, where all the teeth are drawn the same size, so that the structural differences will stand out.

The first group, the *Daphaenus-Amphicyon* line, has the formula $\frac{3}{3}\frac{1}{1}\frac{4}{4}\frac{3}{3}$, the trenchant lower carnassial, the short rather blunt upper carnassial with large deuterocone; upper molar 1 is quite primitive with its wide inner lobe and the inner crescent tending to be simple. It is upper molar 1 that was most modified in the various genera belonging to the group. In *Daphaenus* the crescent is simple; in *Daphaenodon* it begins to divide into two cusps; in *Amphicyon* the cusps are entirely distinct. *Mammacyon* I have placed in this group, but it is highly specialized in that the inner crescent has swollen to make a single cusp filling the whole lobe. This line began with the basal Oligocene and continued through the Miocene but there died out. Most of the species were large dogs, *Daphaenodon rienheimerensis* being the largest of them.

The second group, centering around *Temnocyon*, also has the trenchant lower carnassial, but the upper carnassial is more elongate, and has a good shearing surface. Here molar 1 of the upper series has the inner lobe excavated on its anterior margin and the inner crescent divided into distinct protocone and hypocone. It would look almost as if this inner lobe was bent forward. The species were usually middle-sized dogs. In this group there has been considerable confusion because Cope, when he established *Temnocyon* made *T. altigens* the type, and included in the genus *T. josephi* and *T. wallovianus*. *T. josephi* later became the type for *Mesocyon* (to be discussed below); and *T. wallovianus* is close to *Enhydrocyon*, but differs enough to deserve, probably, a new generic name. Cook's *T. venator* is surely an *Enhydrocyon*, and his *T. precussor* will probably belong elsewhere when the upper dentition is known. The Oligocene genus *Protemnocyon* Hatcher appears to be valid, a less specialized representative of the group. Matthew derived the modern trenchant-heeled genera *Cyon*, *Ictocyon*, and *Lycaon* from *Temnocyon*, and this seems to be probable.

The *Mesocyon* group, typified by *M. josephi* Cope, also has the trenchant-heeled lower carnassial and an elongate sharp upper carnassial, but molar 1 of the upper series is distinctive. Here the inner lobe of the tooth is excavated behind as though the whole tooth were bent

back, the inner crescent has but a median cusp, and the cingulum is restricted to the posterior inner margin. This group is represented only by *M. josephi* Cope, *M. coryphaeus* Cope, and *M. brachyops* Merriam (4) from the John Day; and *M. robustus* Matthew from the lower Rosebud.

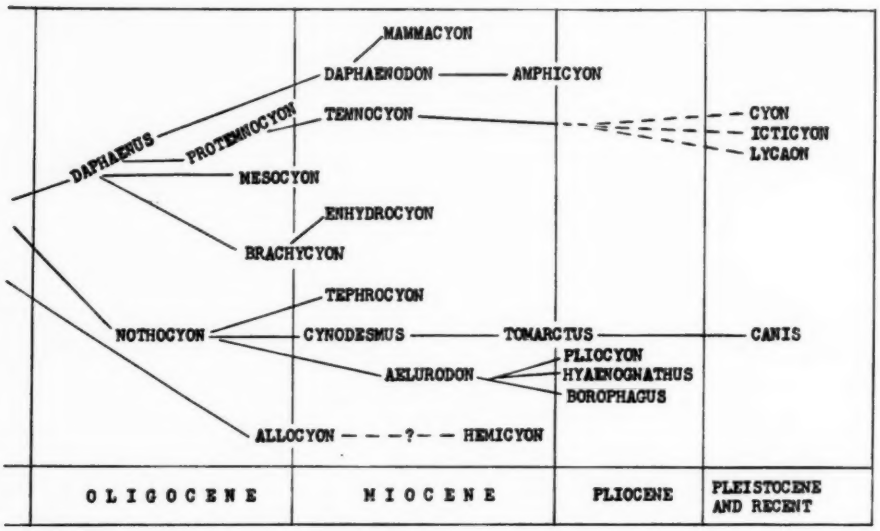

FIG. 6—A suggested phylogenetic tree of the dogs, especially the genera of the Oligocene and Miocene.

The *Enhydrocyon* group is characterized by the trenchant lower carnassial, the elongate upper carnassial, and by the excavation of the inner lobe of upper molar 1 both in front and in back. In its fullest expression the inner crescent has a single median cusp (protocone?) and two tiny cusps (protoconule and hypoconule?) at either upper end. Upper molar 1 is a very distinctive tooth and is fully typified in *Enhydrocyon*. This genus has the molars reduced to 2/2, but there must have been related forms in which this reduction had not taken place. Cook's *Temnocyon venator* belongs in the group, as does also the species known as *Temnocyon wallovianus*, which, however, lacks the tiny cusps at the upper ends of the inner crescent. *Brachicyon* Loomis tends toward this type.

In contrast to the four foregoing groups the next three have the lower carnassial with a basin-like heel.

The earliest group with basin-heeled lower carnassial, the *Nothocyon* group, has a narrow sharp-edged upper carnassial and a simple upper molar 1. Though upper molar 1 is wide and not excavated at either front or back, the inner crescent is always divided into two subequal cusps, protocone and hypocone. The generic name *Nothocyon* was proposed by Matthew for the John Day

species that had generally been assigned to *Galecynus*, a genus of late Eocene dogs of Europe. I feel that the American forms included under the name *Cynodictis* should also be placed in *Nothocyon*, as these small dogs of the Great Plains region are essentially like those of the John Day, and, as has been suggested before, are different from the European *Cynodictis*. There would then be a considerable number of species of these small Oligocene dogs. The line continued on into the Miocene as *Cynodesmus*, into the upper Miocene and Pliocene as *Tomarctus*, and finally into *Canis* of the present. The various genera are distinguished, not by structural differences in the dentition, but by gradual increase in length of leg, reduction of the first digit, and increase in size of the brain case.

A second group of dogs with basin-heeled lower carnassial is represented by the John Day genus *Tephrocyon*. The type species is *T. rurestris* Condon (5). The upper carnassial is similar to that of *Nothocyon*, but has a suggestion of a parastyle. Upper molar 1 is excavated behind, the whole inner lobe seeming to be bent backward somewhat as in *Mesocyon*, but both the inner and the outer crescents are fully developed, the inner with both a protocone and a hypocone, the outer making a cingulum all around this inner lobe. Several other species have been referred to *Tephrocyon*, but they are all either lower jaws or parts of lower jaws and their real relationships can be determined only when further material is available.

The genera *Aleurodon*, *Borophagus* (6), *Hyaenognathus*, and *Pliocyon* constitute another group of dogs with basin-heeled lower carnassial. All are larger dogs with rather blunt cusps on the teeth, and seem to have replaced the *Amphicyon* dogs in the Pliocene. The lower carnassial of *Aleurodon* has the paraconid elongated into sort of a crescent, but this is only an individual feature, for the other genera have this cusp simple and rounded, and progressively blunt. On the upper carnassial there is always a well marked parastyle, and the lobe on which the deuterocone should stand is reduced, without a distinct cusp. Upper molar 1 is relatively simple, with the inner lobe normally developed; the inner crescent has two cusps and the cingulum is fully developed; on the outer side of this tooth, however, the external cingulum is usually lacking. The later representatives of this group tend to become short-faced.

Finally, C. W. Merriam (7) has described a John Day form, under the name *Allocyon*, that stands all by itself. Unfortunately the teeth are worn almost to the roots so that the characters of the lower carnassial and upper molar 1 are indeterminate, but the upper carnassial is unique in that the deuterocone is a large lobe extending from the rear of the tooth onto the metastyle. No other dog has such a deuterocone, and it suggests the *Hemicyon* and bear type of carnassial, but is earlier than any member of that group. The characteristics of the skull are dog-like. It must stand alone until more ma-

terial is found to elucidate it.

Several genera and many species are not considered in the foregoing. Mostly they are based on lower dentition alone, which I do not find adequate for determination of phylogenetic relationship. Without upper molar 1, or at least the upper carnassial, it is very difficult to place the fossil dogs.

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NEW MONACTINELLID SPONGES FROM THE ORDOVICIAN OF WISCONSIN

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ABSTRACT

Spicules of five new monactinellid sponges are described from the Lower Ordovician of Wisconsin. The form-genus *Petrosites* is proposed to include spicules resembling those of the living sponge *Petrosia*.

The rarity of monactinellid sponges in Paleozoic rocks lends particular interest to the recent discovery of spicules of such forms in the Lower Ordovician Oneota dolomite of Wisconsin. The Monactinellida, an important group in the sponge faunas of today, seem to have played a minor role in Paleozoic times. As, however, these sponges are usually represented in fossil form only by detached and scattered spicules, mostly of small size, they have probably been overlooked by paleontologists.

Early monactinellid sponges.—Monactinellid sponges are known to have been well developed in Medial Cambrian times. Walcott (1) described twenty-three species, grouped in ten genera, from the Middle Cambrian Burgess shale of British Columbia, and at least two genera of Monactinellida occur in the Little Metis shale of Quebec (2). Walcott (3) also reported a Lower Cambrian sponge, which he considered a possible monactinellid, from what is now known as the Parker formation of northwestern Vermont. A possible Ordovician occurrence of a monactinellid was reported from Esthonia by H. Bekker (4). He compared the fossil to Walcott's genus *Hazelia*, but Öpik (5) states that the specimen is probably a poor impression of a bryozoan.

The only other mention of Ordovician Monactinellida known to the writers is in a paper by William Pulfrey (6), describing the association of sponge spicules with iron ores in North Wales. The presence of a form doubtfully referred to *Reniera* is noted, and the horizon is given as "Arenig?" As far as the writers have been able to learn, no authentic Silurian Monactinellida are known. Only two genera of the order have been reported from the Devonian and eight from the Carboniferous.

Locality of present specimens.—The spicules here described from the Oneota dolomite were kindly submitted to the writers by Professor C. E. Needham (7), who had reported their discovery in *Science* in 1933. They are believed to be the first monactinellid sponges recognized from the Ordovician of North America. The locality of their discovery is given as "U. S. Highway 12, 3 or 4 miles south of Springfield Corners,

Wisconsin." Needham described the Oneota formation at this place as "medium to thick bedded dolomite . . . carrying a few lenses and thin beds of chert." The rock enclosing the spicules is a dense, buff dolomite. It was obtained from a bed that contained no chert. The siliceous spicules were readily segregated by dissolving the enclosing rock in warm dilute hydrochloric acid, and picking them from the sandy residue with a fine brush.

With regard to the stratigraphic relationship of the Oneota dolomite, Professor W. H. Twenhofel informs the writers that its exact status as a subdivision of the "Lower Magnesian" is not fully understood. The beds from which the sponge spicules were collected are, however, undoubtedly a part of the "Lower Magnesian" or Prairie du Chien group. This group is correlated in a general way with the upper Ozarkian of Ulrich or lower Beekmantown. More must be learned of the faunas before positive correlations can be made for any particular part of the group.

Character of the spicules.—Siliceous sponge skeletons, when unaltered, are composed of amorphous silica and are characterized by having central axial canals, which contained organic matter while the sponge was living. The spicules from this locality however, appear as aggregates of fine quartz crystals. Fortunately the alteration to crystalline form has taken place in such a way that the axial canals are still recognizable in a large percentage of the specimens when viewed in transmitted light, thus proving that the fossils were originally siliceous and not replacements of calcareous spicules.

The megascleres, which are just visible to the naked eye, are comparable in size to those of many modern monactinellids. They vary in length from 0.16 mm. to 0.91 mm., and have diameters of 0.01 mm. to 0.041 mm. No microscleres or flesh spicules, such as are present in several modern groups of monactinellids, were found. It is possible, however, that such spicules were originally present and were lost by subsequent alteration, whereas the larger and more resistant megascleres were preserved.

All of the spicules are of simple diactinal types, comparable to those of primitive, living, halichondroid sponges. Similar simple acerate diactinal spicules occur in the bodies of living tetractinellids, but always in association with recognizable tetraxons.

In Monactinellida of which only spicules are preserved, and of which no evidence of the arrangement of spicules in life is retained, the species must be determined on such features as the form and size of individual spicules, nature of the cross section, curvature, termination, gradation in thickness, position of loci of curvature, and nature and extent of the axial canals. The genera must be regarded as form genera only, and there is, therefore, not necessarily a close relationship between the species included in a genus.

Reference to living sponges shows

that there is considerable homogeneity of spicule type within many species, but a few sponges show some variety in the spicule types occurring in a single specimen. It is here considered advisable, for purposes of description, to place the spicules in named groups, admitting the possibility that some of the differing types may have belonged to a single species, even in the absence of known intergrading forms connecting them.

The Ordovician spicules here described seem to have present day counterparts in every case in the suborder Halichondrina, and appear to be most closely comparable to members of the family Homorhaphidae. The resemblance between species so different in age is probably more superficial than genetic; but, in the absence of evidence of the arrangement of parts, the practice is adopted of provisionally referring the spicules to those groups which they seem, at least superficially, to resemble.

SYSTEMATIC DESCRIPTIONS

Phylum PORIFERA

Class SILICISPONGIA

Order MONACTINELLIDA Zittel

Siliceous sponges with uniaxial megasclera (8).

Suborder HALICHONDRINA Vosmaer

Typically non-corticate; skeleton usually reticulate; megasclera usually either oxea (straight spicules pointed at both ends) or styli (pointed at one end and rounded at the other).

Genus HALICHONDRITES Dawson, 1899

Halichondrites DAWSON, *1889*, Roy. Soc. Canada, Trans., vol. 7, sec. 4, p. 52.

Dawson proposed the name *Halichondrites confusus* for a sponge from the Metis shale of Quebec without giving a generic characterization. The specimens were described as

> oval or irregular masses of small, simple spicules . . . the masses without any definite arrangement or root spicules. In the best preserved specimens the spicules appear to be biacerate . . . and to be in two series, inclined at a very oblique angle to each other.

A sketch, illustrating the fossil, shows simple, elongate, biacerate spicules arranged in a rhomboidal network. Apparently the skeletal elements were not fused, since some spicules are represented as free and the description of the mode of preservation makes it evident that the spicular arrangement in life might be retained even after decay of the binding organic material.

Walcott (9) recovered from the Burgess shale a halichondroid sponge characterized by a dermal layer resembling that of the specimens described by Dawson as *Halichondrites confusus*. He described the form as *H. elissa* and designated it as the type of the genus. Dawson's genus was monotypic, however, and his *H. confusus* alone can be the genotype. Walcott's species *elissa* is to be construed as an allogenotype (This term was proposed by the writers in a paper read before the Paleontological Society at its meeting in December, 1935, to designate a species used in the redefinition of a genus to furnish important information not supplied by the known specimens of the genotype).

The skeleton of *H. elissa* is described by Walcott as composed of

> long, slender rods formed of hairlike spicules. The rods cross each other at a narrow sharp angle; they are held together by a mass of fine

acerate spicules that cross them obliquely and at all angles; buried in this confused mass there is a very fine rectangular mesh . . . presumably formed of small acerate spicules . . . At the upper border of the body the minute acerate spicules appear to be embedded in a membrane . . . Most of them cross each other obliquely to form a dense mass . . . The same fine spicular membrane . . . appears to have covered them (the rods) everywhere before the membrane was removed by splitting the matrix from the surface of the sponge.

Neither Dawson nor Walcott give accurate drawings of the spicules of their species, but the descriptions and Dawson's illustration show that the bodies of the sponges referred to *Halichondrites* contained spicules of the same general type as those here provisionally referred to the genus.

The spicules here described are simple, elongate, moderately slender oxea; smooth, subcylindrical, without spines or nodes. Terminations rather acute points; the spicules slightly curved, with the loci of curvature characteristically nearer one end; a slight, uniform thickening of those portions of the spicule about the loci of curvature. The diagonal arrangement of spicules characterizing *Halichondrites* could not be observed in our Oneota specimens. A comparison with living forms showed a resemblance in spicule type between the forms here referred to *Halichondrites* and members of *Halichondria* and related living genera. It is interesting to note in this connection that from the standpoint of simplicity of form and arrangement of spicules, *Halichondria* has been considered to be the most primitive of living sponges (8).

HALICHONDRITES? ACTINIFORMIS
Howell and Landes, n. sp.

Text-figures 1–6

Spicules just visible to the naked eye, averaging 0.38 mm. in length, 0.018 mm. in diameter. Diameter maximum near locus of curvature, decreasing gradually, to a point near the end, where rapid tapering begins. Terminations rather acute. Curvature moderate, somewhat variable; loci of curvature usually located nearer one end, ratio of the parts ranging from 1:1 to 1:3. When the spicules are placed in a position to show maximum curvature, the line of the convex curve is seen to remain uniform throughout its length, while the concave curve remains fairly uniform to a point near the end, where it changes abruptly to terminate the spicule in a sharp point. When the spicules are placed in a position to show no curvature (rotated 90° around the long axis) they are seen to remain of uniform thickness to a point near the end, where rapid tapering begins. An axial canal is visible in many specimens, and seems nearly to reach the end of the spicule.

Types: Princeton Univ. Holotype, 41924; paratypes, 41925–41927.

HALICHONDRITES? ROBUSTUS
Howell and Landes, n. sp.

Text-figures 7, 8

Relatively large, oxeote spicules averaging 0.91 mm. in length, 0.041 mm. in diameter. Terminations acute. Curva-

FIGS. *1–21*—Ordovician monactinellid spicules, ×220; Princeton Univ. cat. nos. in parentheses.

1–6—*Halichondrites actiniformis* Howell and Landes, n. sp. *1*, Holotype (41924); 2–6, paratypes (41925–41927). (p. 56)

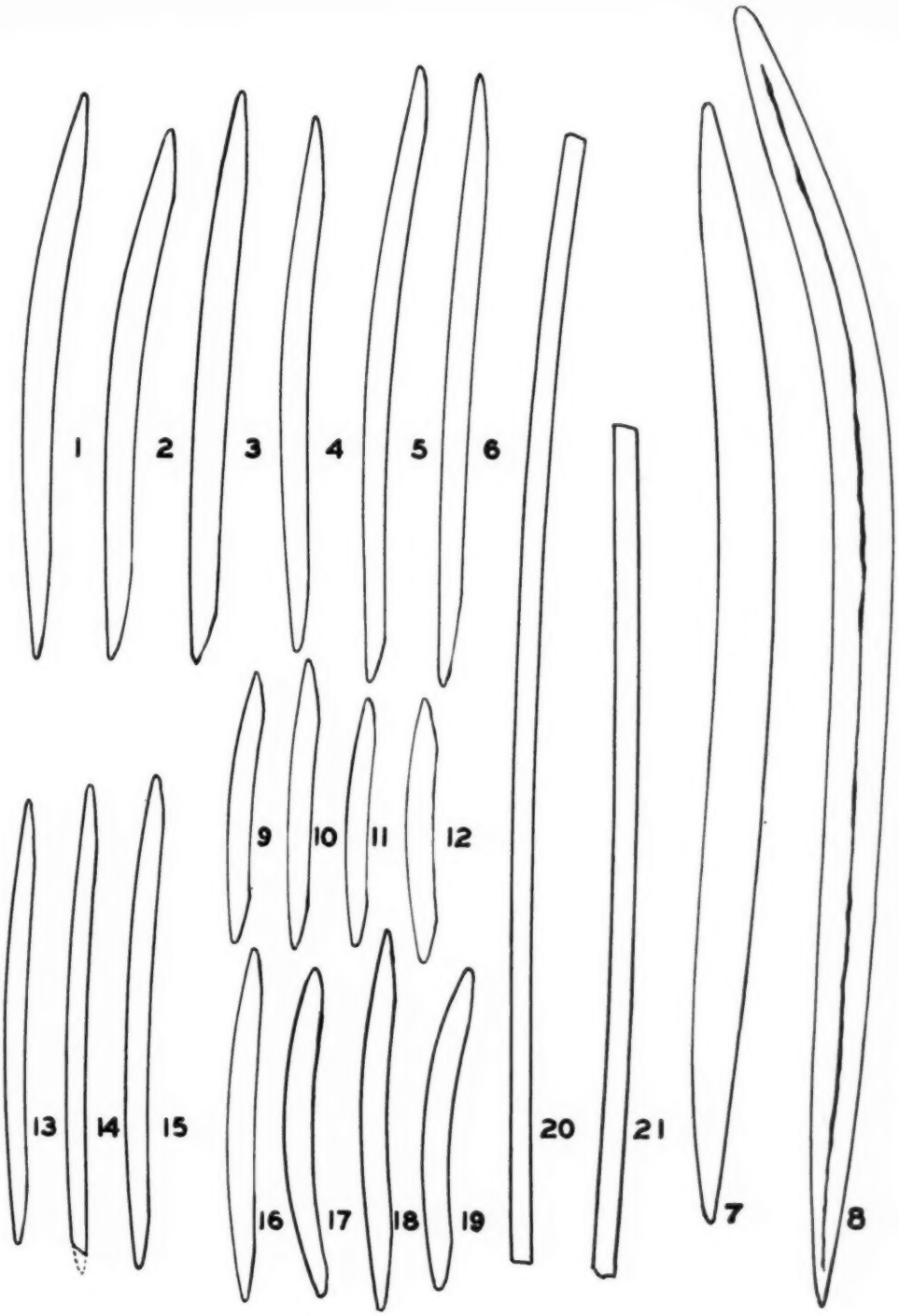
7,8—*Halichondrites robustus* Howell and Landes, n. sp. *7*, Holotype (41928); *8*, paratype (41929). (p. 56)

9–12—*Petrosites humilis* Howell and Landes, n. sp. *9*, Holotype (41931); *10–12*, paratypes (41932–41934). (p. 58)

13–15—*Petrosites tenuis* Howell and Landes, n. sp. *13*, Holotype (41935); *14–15*, paratypes (41936). (p. 58)

16–19—*Petrosites variabilis* Howell and Landes, n. sp. *16*, Holotype (41937); *17–19*, paratypes (41938). (p. 58)

20,21—Slender spicules without terminations; affinities uncertain (41940). (p. 58)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ture rather pronounced; loci of curvature markedly nearer one end, ratio of the parts ranging from 4:5 to 2:3. Uniform thickening visible near loci of curvature, as viewed in the position showing maximum curvature, ranging from just visible to quite pronounced. The termination is seen to be formed by a break from the concave curve as viewed in the position showing maximum curvature. Axial canal clearly visible, reaching nearly to the end of the spicule.

Types: Princeton Univ. Holotype 41928; paratypes, 41929.

Genus PETROSITES Howell and Landes, n. gen.

A form genus to include simple, diactinal spicules of the following description. Spicule oxeote, cylindrical, smooth, without nodes; straight or gently curved. Curvature generally symmetrical, without defined locus of curvature. Spicule of fairly uniform diameter or tapering faintly to points near the end, where rapid tapering begins. Terminations acute or slightly rounded, formed by a break in the concave curve when the spicule is viewed in a position showing curvature. Axial canal terminates within the spicule. The modern genus *Petrosia* has spicules at least superficially resembling those referred to *Petrosites*.

Genotype: *Petrosites humilis* Howell and Landes, n. sp.

PETROSITES HUMILIS Howell and Landes, n. sp.

Text-figures 9–12

Spicules very small, smooth, cylindrical, oxeote, terminating in acute or but slightly rounded points. Length, 0.16 mm. to 0.20 mm.; diameter, 0.014 mm. to 0.02 mm. Faint symmetric curvature without defined loci of curvature. Terminations formed by break in concave curve relatively near the ends of spicules, the convex curve remaining uniform as viewed in a position showing maximum curvature. Axial canal, visible in a few specimens, variously modified, but seems to terminate well within the spicules.

Types: Princeton Univ. Holotype, 41931; paratypes, 41932–41934.

PETROSITES TENUIS Howell and Landes, n. sp.

Text-figures 13–15

Spicules slender, smooth, cylindrical. Average length, 0.3 mm; diameter, 0.011 to 0.014 mm. Curvature faint, usually symmetrical. Terminations acute. Diameter fairly uniform throughout length; terminations formed by rapid tapering near the ends of the spicules. Axial canal not observed.

Types: Princeton Univ. Holotype, 41935; paratypes, 41936.

PETROSITES VARIABILIS Howell and Landes, n. sp.

Text-figures 16–19

Spicules oxeote, thick, short, smooth, cylindrical, with fairly acute terminations. Length, 0.21 mm. to 0.26 mm., averaging 0.24 mm.; diameter, 0.016 mm. to 0.025 mm., averaging 0.02 mm. Straight or curved. Most specimens of fairly uniform thickness to a point near the end, where rapid tapering begins; a few specimens taper gently from a subcentral point to points near the end, where rapid tapering begins. Termination formed by a break in the concave curve as seen in a position showing maximum curvature. Axial canal faintly visible in only a few specimens.

Petrosites variabilis is readily distinguished from *Petrosites humilis* by its greater length and stoutness, as well as by the frequency of specimens with more pronounced curvature.

Types: Princeton Univ. Holotype, 41937; paratypes, 41938.

INCERTAE SEDIS

Text-figures 20, 21

Elongate spicules lacking terminations and without definite curvature were obtained from the sandy residues. A typical specimen had a diameter of

0.018 mm. and a length of 0.75 mm. Although these spicules probably represent fragments of elongate spicules from some of the sponges described, no definite assignment of them to genera or species could be made.

Figured specimens: Princeton Univ., 41940.

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Note: The manuscript of this paper was received by the editor April 30, 1935.

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NOTES ON THE DEVONIAN CRINOID FAUNA OF THE CEDAR VALLEY FORMATION OF IOWA

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ABSTRACT

Within the last few years, a number of well-preserved Devonian crinoids have been added to the collections of the University of Iowa. Five of them representing new species, and three others more adequately illustrating species founded on fragmentary material in the past are described and figured.

The marly limestone ledges of the Cedar Valley formation of Iowa are at many places filled with fragmentary crinoidal remains, but calyces sufficiently well preserved to allow identification are rare. Recent work in the area around Iowa City, conducted mainly by students of the State University, has yielded duplicates of almost all of the species previously described from the formation. Among these recent collections are a few species that are new and a considerable number of specimens that more adequately illustrate previously described species.

The early work of Owen, Hall, Barris, White, Worthen, Wachsmuth, Springer, and Calvin has all been summed up by Thomas (1) in 1929.

The Cedar Valley formation consists of three distinct members, each having a definite fauna. The exact stratigraphic relations of these three members is not definitely known at the present time, though it seems evident that the fauna of the Cedar Valley should not be considered a unit. The lower member, with the *Prismatophyllum profundum* and *Atrypa independencis* faunal units, thickens rapidly to the north in Iowa. A sharp faunal break and local evidences of erosion mark its contact with the overlying Littleton member. Locally the fauna contains many specimens of *Newberria* and *Stereocrinus*, suggesting relationship with the Mineola limestone of Missouri.

All of the crinoids with which this paper deals have been collected from the middle, or Littleton, member. It appears to be thickest in the southern portion of the region and is separated from the overlying Coralville member by a sharp faunal and lithologic break. Faunally it appears to represent some portion of the Traverse group of Michigan.

The fauna of the Coralville member suggests a recurrence of the *Prismatophyllum profundum* fauna.

Acknowledgments.—The writer wishes here to make acknowledgments as follows: to the late C. H. Belanski, of the University of Iowa, through whose efforts by far the greater number of crinoids used in this report were collected; to the late Dr. A. O. Thomas, of

the University of Iowa, for cleaning and preparing a number of the specimens, with future publication in view; to Mr. C. T. Kohn, geologic artist of Tulsa, who illustrated all specimens used in the report; to Dr. M. A. Stainbrook, of Texas Technological College, for collection of several of the specimens; to Dr. A. K. Miller, of the University of Iowa, who made available the entire collection of Devonian crinoids of the University.

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SYSTEMATIC DESCRIPTIONS

Order CAMERATA Wachsmuth and Springer

Family BATOCRINIDAE Wachsmuth and Springer

Genus MEGISTOCRINUS Owen and Shumard, 1852

MEGISTOCRINUS PERNODOSUS Thomas

Figures 1, 2

Megistocrinus pernodosus THOMAS, *1929*, Iowa Geol. Survey, vol. 29, p. 456, pl. 41, figs. 5–23.

This species was described originally from isolated plates and stems. In 1928 Stainbrook discovered eight well preserved calyces of this species in a creek bed about two miles south of Brandon, Iowa. Portions of the stem and arms were preserved on some of the specimens. Later search in the same creek bed by the writer produced a few more rather poor specimens.

Dorsal cup: Calyx globose, height, 24 mm., width, 25 mm. in mature specimens. Radial nodes protruding below flattened base; basals three, flat, undecorated, corners protruding slightly beyond stem segments; radials five, hexagonal, extremely nodose, slightly smaller than primibrachs; anal heptagonal, nodose, smaller than radials; primibrachs two—first hexagonal, slightly larger than radials; second pentagonal, half the size of the first; secundibrachs two, hexagonal, occasionally heptagonal, second smaller than first; followed by free arm plates; small intersecundibrachs occasionally present; primary interbrachial hexagonal, as large as radial. Normal interbrachial succession 1–2–2–2, occasionally 1–2–3–2. Anal interradius wide connecting broadly with the tegmen; normal succession 1–3–5.

Ventral disk: Slightly inflated, plates nodose, smaller than those of dorsal cup; ambulacral plates slightly larger; orals not conspicuous. Tube long, stout, slightly eccentric, consisting of heavy very nodose plates.

Arms: Only fragmentary portions preserved; widely flaring, biserial, branching once 9 mm. above base; brachials small, normally 22 in 10 mm., pinnules closely packed, pinnulars short.

Column: As bizarre and decorated as calyx; columnals alternately expanded, edges smoothly rounded; largest 7 mm. in diameter, smallest 4 mm. in diameter; lumen small.

Relationships.—The genus *Megistocrinus* apparently reaches its culmination in the Cedar Valley formation. *M. pernodosus* is closely related to *M. nodosus*, from the Traverse group of Michigan, from which it differs in its more nodose plates.

Occurrence.—Upper portion of Littleton member, Cedar Valley limestone; usually in *Atrypa waterlooensis* zone associated with *Strobilocystites calvini*, *Athyris vittata* and *Atrypa waterlooensis*.

Figured specimens: Univ. Iowa, 2000, 1999. Two miles south of Brandon, Iowa.

Order FLEXIBILIA Zittel

Family TAXOCRINIDAE Bather (em. Springer)

Genus EUTAXOCRINUS Springer, 1906

EUTAXOCRINUS GRACILIS (Meek and Worthen)

Figure 3

Taxocrinus gracilis MEEK and WORTHEN, *1865*, Acad. Sci. Philadelphia, Proc., vol. 17, pp. 142–143.—*1868*, Illinois Geol. Survey, vol. 3, p. 421, text fig., pl. 13, fig. 3.—WACHSMUTH and SPRINGER, *1879*, Rev. Paleocrinoidea, p. 48.

Rhodocrinus (Taxocrinus) gracilis SHUMARD, *1866*, Acad. Sci. St. Louis, Trans., vol. 2, p. 397.

Eutaxocrinus gracilis SPRINGER, *1920*, Crinoidea Flexibilia, p. 367, pl. 49, figs. 8a, b. —THOMAS, *1920*, Iowa Geol. Survey, vol. 29, p. 471, pl. 44, figs. 17–18.

This species has been adequately described but none too well figured because of the fragmentary preservation of all hitherto described specimens. A considerable number of well preserved specimens of this species are now available.

Occurrence.—Littleton member, Cedar Valley limestone; fairly abundant in the green shaly crinoidal limestone layer a short distance below the *Prismatophyllum* reef.

Figured specimen: Univ. Iowa, 1993. Quarry, Buffalo, Iowa.

Order INADUNATA Wachsmuth and Springer

Family BOTRYOCRINIDAE Bather

Genus BOTRYOCRINUS Angelin, 1878 (em. Bather, 1891)

BOTRYOCRINUS THOMASI Laudon, n. sp.
Figures 4–6

Species represented by four specimens, all incomplete. Calyx of largest, width, 11 mm., height, 10 mm.; calyx expands rapidly at base so that full width is attained at tops of basals.

Dorsal cup: Base slightly excavated so that nodose mid-surfaces of small infrabasals protrude below the first stem segments; basals 5 mm. wide, 5 mm. high; hexagonal except on posterior side where they are heptagonal; plate markings ornate, ridges radiate from the center of each plate, corners of plates marked by deep depressions; radials wider than high, averaging 5 mm. wide, 4 mm. high. Arm facets constricted, occupying only small portion of upper surface of each radial. Radianal small, oblique, quadrangular; anal smaller than radials, width, 3 mm., height, 4 mm.

Ventral sac: Not preserved.

Arms: Fragments of two arms preserved on one specimen; arms branch once on the third primibrach; brachials higher than wide, slightly over 1 mm. high.

Column: Round, 2 mm. in diameter next to calyx. Columnals thick, alternately expanded in top, equal in width in lower column.

Occurrence.—Littleton member, Cedar Valley formation. Three specimens came from the quarry at Linwood, Iowa; and one from Linders Boat Landing, Iowa river, north of Iowa City.

Types.—Univ. Iowa, 1991 (holotype), 1990 (paratype).

FIGS. *1, 2—Megistocrinus pernodosus* Thomas. *1*, Lateral view showing right posterior and right anterior rays, ×1, (Univ. Iowa, 2000). *2*, Posterior, showing lower arms, ×1, (Univ. Iowa, 1999). (p. 61)

3—Eutaxocrinus gracilis (Meek and Worthen), anterior, showing stem and arms, ×1, (Univ. Iowa 1993). (p. 61)

4–6—Botryocrinus thomasi Laudon, n. sp. *4*, Paratype, posterior view, ×1, (Univ. Iowa 1991); *5*, anterior of same, ×1. *6*, Holotype, ×1, (Univ. Iowa 1990). (p. 62)

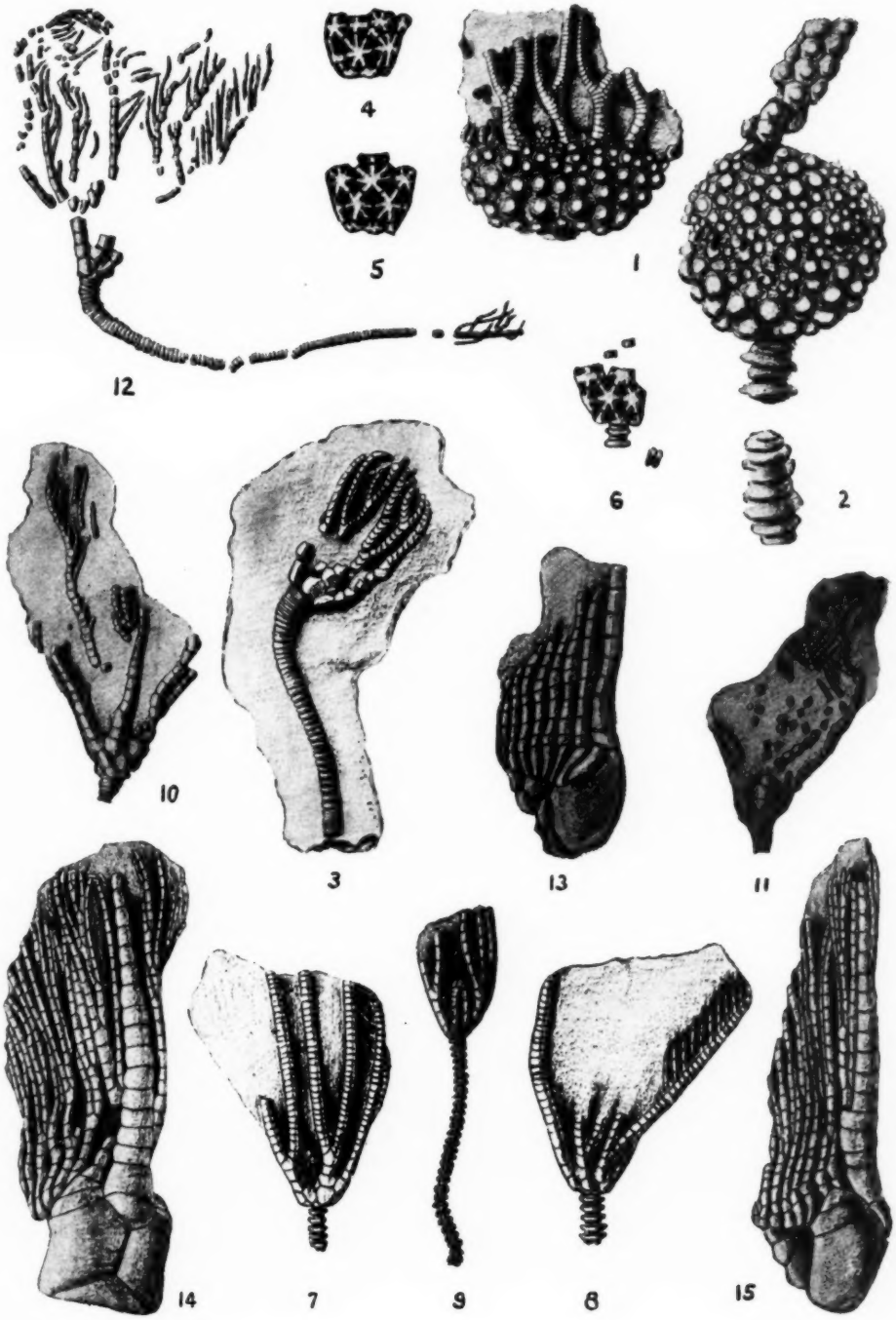
7, 8—Decadocrinus crassidactylus Laudon, n. sp. *7*, Holotype, posterior view, ×1, (Univ. Iowa 1998); *8*, holotype, anterior, ×1. (p. 64)

9—Decadocrinus pachydactylus Laudon, n. sp. *9*, Holotype, posterior aspect, ×1, (Univ. Iowa 1997). (p. 64)

10–12—Decadocrinus spinulifer Laudon, n. sp. *10*, Paratype, right anterior aspect, ×1, (Univ. Iowa 1996); *11*, left posterior, same specimen. *12*, Holotype, lateral aspect, ×1, (Univ. Iowa 1995). (p. 65)

13—Halysiocrinus barrisi (Worthen), anterior, showing characteristic arms, ×1. (Univ. Iowa 1994). (p. 65)

14, 15—Halysiocrinus elephantinus Laudon, n. sp. *14*, Holotype, left anterior aspect, ×1, (Univ. Iowa 1992); *15*, anterior view of same ×1. (p. 66)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Family POTERIOCRINIDAE Roemer

Genus DECADOCRINUS Wachsmuth and Springer, 1879

DECADOCRINUS CRASSIDACTYLUS Laudon, n. sp. Figures 7, 8

Species known from single specimen; length, 35 mm. from base of calyx to broken ends of arms; estimated length for complete calyx and arms, 38 mm.; width at top of radials, 11 mm.

Dorsal cup: Infrabasals small, almost hidden beneath column; basals nodose, smaller than radials, width, 3 mm., height, 2 mm., except the posterior which is 3 mm. high; radials 4 mm. wide, less than 2 mm. high; interradial sutures deeply impressed in calyx; radianal smaller than basals, in contact below with posterior and right posterior basals, laterally with anal and right posterior radial, above with right primary tube plate; anal smaller than radianal, projecting above general level of radials, in contact below with truncated posterior basal and radianal, laterally with left primary tube plate and right posterior radial, above with middle primary tube plate.

Ventral sac: Not observed.

Arms: Thick, club-like, branching on primaxil, straight with little incurving at tips; brachials tending slightly to cuneiform, thin, averaging 7 per. cm. in proximal and 12 per. cm. in distal portion of arms; pinnules long, stout, characterized by short pinnulars averaging 16 to 1 cm.

Column: Only a small portion of the proximal part of the column is preserved; pentagonal; columnals alternately expanded, corners carrying low rounded nodes.

Relationships.—Closely related to *D. vintonensis* (2), also from the Cedar Valley limestone. Easily separated from *D. vintonensis* in that *D. crassidactylus* has a heavier arm structure and thinner brachials. It is also somewhat similar to *D. killawogensis* (3) from the Portage of New York; the Portage species has heavier brachials.

Occurrence.—Littleton member, Cedar Valley formation. Collected by Belanski on Rapid Creek, Johnson County, Iowa.

Type.—Univ. Iowa, 1998 (holotype).

DECADOCRINUS PACHYDACTYLUS Laudon, n. sp. Figure 9

Species known from single specimen preserving part of the stem, calyx, and a portion of the arms. Height of calyx, 4.5 mm., width at top of radials, 6 mm.

Dorsal cup: Calyx cone-shaped, expanding slowly, deep in comparison to width at top of radials. Infrabasals comparatively large, projecting beyond stem to make a definite part of calyx wall, rising 1 mm. above stem on lateral wall; basals smaller than radials, flattened, about equidimensional; radials 1.5 mm. high, 2 mm. wide; interradial sutures deeply impressed; radianal larger than anal, smaller than posterior basal, in the normal position in contact beneath with posterior and right posterior basals, with anal and right posterior radial laterally, with right primary tube plate above; anal resting on truncated upper surface of posterior basal, in contact laterally with radianal, right primary tube plate, and left posterior radial; supporting middle tube plate.

Ventral sac: Lower portion of posterior side visible. Plates deeply impressed at corners, giving a stellate appearance.

Arms: Branch once on second brachial, making 10 to the species; arm facets occupy entire upper surface of radials; brachials thick, normally 6 in 10 mm.; little tendency toward cuneiform; pinnules not visible.

Column: Sharply pentagonal; columnals alternately expanded, with every fourth expanded more than second; corners carrying low nodes.

Relationships.—Somewhat similar to the form described by Williams (4) as *Poteriocrinus clarkei.* The New York form has, however, a longer calyx, the

brachials do not occupy the full width of the radials, and the arm brachials are not as heavy.

Occurrence.—Littleton member, Cedar Valley formation, Brandon, Iowa; Belanski, collector.

Type.—Univ. Iowa, 1997 (holotype).

DECADOCRINUS SPINULIFER Laudon, n. sp.
Figures 10–12

Species represented by a large number of specimens, usually badly damaged owing to its fragile character. Holotype preserved on slab with remnants of eight other specimens. Length of calyx and incomplete arms of holotype, 34 mm.; length of calyx and arms on one paratype, 46 mm.; width of calyx at top of radials, 8 mm.

Dorsal cup: Expanding rapidly; plates extremely nodose, with interradial sutures deeply impressed; infrabasals small, projecting only slightly beyond stem; basals smaller than radials, highly nodose, width, 2 mm., height, 2 mm.; posterior basal truncated, supporting anal plate; radials nodose, expanding upwards, width, 3 mm., height, 2 mm.; arm-facet curved, occupying entire upper surface of radial; radianal smaller than radial, in typical position in contact with posterior and right posterior basals below, the anal and right posterior radial laterally, with right primary tube plate above; anal small, not rising above radials.

Ventral sac: Short, reaching approximately two-thirds of length of arms; plates hexagonal, each bearing four ridges which diverge from center; angle of divergence small, giving tube a horizontally ribbed appearance.

Arms: Long, very slender; brachials markedly cuneiform; pinnules long, exceedingly coarse for size of arms.

Column: Tapering rapidly, twice length of calyx and arms, bearing long slender cirri near distal end; columnals thin, slightly expanded at proximal end.

Relationships.—This species apparently has no close relatives in the Devonian of New York. It exhibits an arm structure that is similar to that of *D. multinodosus* Goldring (5), from the Hamilton of New York, but differs widely in calyx structure.

Occurrence.—Littleton member, Cedar Valley formation, quarry at Linwood, Iowa. Abundant in shaly limestones immediately below the *Prismatophyllum* reef.

Types.—Univ. Iowa, 1996 (holotype), 1995 (paratype).

Family CALCEOCRINIDAE Meek and Worthen

Genus HALYSIOCRINUS Ulrich, 1886

HALYSIOCRINUS BARRISI (Worthen)
Figure 13

Calceocrinus barrisi WORTHEN, *1875*, Illinois Geol. Survey, vol. 6, p. 510, text fig.—WACHSMUTH and SPRINGER, *1885*, Rev. Paleocrinoidea, pp. 276–281.—BATHER, *1893*, Crinoidea of Gotland, Pt. 1, p. 66, listed.

Halysiocrinus carinatus SPRINGER, *1926*, Smithsonian Inst., Publ. 2871, p. 122, pl. 29, fig. 25.

Species originally described from a single specimen showing anterior radial, left posterior radial, left anterior infraradial and superradials. Springer (6) referred another specimen of this species to *H. carinatus*, of the Traverse group of Michigan. The specimen figured by Springer was much more complete than the originally described specimen.

Dorsal cup: Basals three, one not in contact with stem; triangular piece consisting of three basals 16 mm. wide. Suture between basal and left anterior inferradial deeply excavated; left anterior inferradial triangular, 16 mm. wide, 4 mm. high, separated from left anterior superradial by 7 mm.; large, recurved anterior and left posterior radials constricted a short distance back of first arm axil, resembling an extra arm axil; left anterior superradial small, triangular, height, 3 mm., width, 6 mm.; right anterior and posterior inferradials in contact below anal, deeply grooved by stem; anal plates heavy, grooved for

stem; lower plates little covered by arms.

Arms: Axillary plates 10, first not carrying an arm; proximal 9 mm. wide, distal 1 mm. wide; arms 9, branching more than once; next to median arm on sixth brachial, in outer arms on third brachial; median arm slender, tapering little, sutures not deeply impressed; second brachial much longer than others.

Relationships.—Closely related to *H. carinatus*, of the Traverse group, differing in that the Michigan form has a much shorter calyx and the median arm is more slender. Also closely related to *H. elephantinus*, n. sp., that occurs higher up in the Cedar Valley beds. The short inflated brachials of the median arm, and the more slender arms separate it from *H. barrisi*.

Occurrence.—Lower portion of the Littleton member, Cedar Valley limestone, Linwood quarry, Linwood, Iowa; collector, Belanski.

Figured specimen: Univ. Iowa, 1994.

HALYSIOCRINUS ELEPHANTINUS Laudon, n. sp.
Figures 14, 15

Fragmentary plates of several species of *Halysiocrinus* occur fairly abundantly throughout the Linwood member of the Cedar Valley limestone. The present species is represented by a considerable number of scattered calyx plates and one fairly complete crown, in which only the basals are missing. The specimen measures 63 mm. from the base to the tip of the median arm; width of calyx, 18 mm. height, 15 mm.

Dorsal cup: Basals missing; triangular cavity 15 mm. wide, 4 mm. high; left anterior inferradial 16 mm. wide, 4 mm. high, separated from left anterior superradial by 7 mm. where left posterior and anterior radials come in contact; left posterior and anterior radials 18 mm. wide, 15 mm. high, constricted laterally back of their contact with first main arm axil; left anterior superradial triangular, 8 mm. wide, 4 mm. high; right anterior and posterior inferradials small, in contact beneath anal, deeply grooved by stem; right anterior and posterior superradials missing; anal plates wide, broadly rounded, first two deeply excavated for stem.

Arms: First axillary plate 10 mm. wide, 2 mm. high, carrying no arm, curved and deeply excavated in its contact with radials, suggesting mobility; remaining axils 9, rapidly tapering so that most distal is less than 1 mm. in diameter; main axils curve downward in a manner to enfold anal structure but not stem. Arms long, slender, branching more than once, next to median ray 6 times. Brachials twice as long as wide; first brachial of median arm 9 mm. high, and 4 mm. wide; median arm 43 mm. long, carrying 16 brachials, less than 1 mm. in width in outer extremity; brachials round, definitely not keeled, sutures deeply impressed, giving brachials an inflated appearance.

Relationships.—Separated from *H. carinatus*, of the Traverse, and *H. barrisi*, of the Cedar Valley, by its slender arms and thin inflated brachials of the median arm.

Occurrence.—Linwood member, Cedar Valley limestone, Johnson County, Iowa.

Type.—Univ. Iowa, 1992 (holotype).

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PALEONTOLOGICAL NOTES

SPIRIFER DIVARICATUS HALL IN PENNSYLVANIA

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ABSTRACT

For the first time *Spirifer divaricatus* Hall is unquestionably identified from the Hamilton group of Pennsylvania, extending its geographic range and aiding correlation between Pennsylvania and New York.

Distribution of Spirifer divaricatus *Hall.*—*Spirifer divaricatus* Hall, a well-known Middle Devonian brachiopod, is found chiefly in New York and Ontario, where it seems to be fairly common, and has also been recorded southwestward in Kentucky and Alabama. It appears to be confined to the Hamilton group of formations and the Onondaga limestone, or their equivalents, in the north, and to the Onondaga formation only in the south. In his work on the Hamilton of New York, Cooper (1) has mentioned its importance there, particularly as an indicator of the Centerfield limestone member, at the base of the Ludlowville formation of middle Hamilton age. The fossil seems not to have been reliably reported from any Hamilton locality directly south of New York. No occurrence is cited from New Jersey or Maryland. Dr. Charles Butts writes, "I have *Sp. divaricatus* in the Onondaga at several places in S.W. Va. . . ." (2). The fossil is said to have been found by I. C. White in Pennsylvania (3). This statement cannot be verified, and paleontological data accredited to I. C. White, experience shows, are to be used with the utmost caution. Not only were his identifications faulty, but he was prone to making incorrect stratigraphic assignments of faunas. Thus, he mistook a middle Hamilton coral reef in Monroe County for the Tully limestone, and reported *Spirifer disjunctus* from the same region, where it is totally unknown. These remarks are not meant to disparage White's valuable contribution to the stratigraphy of Pennsylvania, but are given as a word of caution relative to the acceptance of his data by those unfamiliar with recent developments in stratigraphic and paleontologic studies in the State.

Occurrence in Pennsylvania.—Up to the spring of 1935, after five years of intensive collecting of Devonian fossils in Pennsylvania, the writer had not seen an example of *Spirifer divaricatus* from the State. He had remarked upon its absence, especially after familiarizing himself to a certain extent with the New York Hamilton faunas and stratigraphic succession. In occasional published lists of Devonian fossils from Pennsylvania, he has invited comparison with the New York faunas, noting particularly that the number of species in Pennsylvania is apparently somewhat less than in New York. The absence of *Spirifer divaricatus* would conform with such a diminution.

Under date of May 18, 1935, however, the writer received a letter from Dr. Lincoln Dryden of the Department of Geology, Bryn Mawr College, requesting him to look over a collection of Devonian fossils that Doctor Dryden and his students had recently made from the Hamilton in Monroe County, including the same reef which White had miscalled Tully. Doctor Dryden remarked that he suspected one of the brachiopods of being *Spirifer divaricatus*. Upon receipt of the

specimens, Doctor Dryden's suspicions were confirmed. A single example was present of *Spirifer divaricatus*, which specimen has been generously presented to the Pennsylvania Topographic and Geologic Survey by its discoverer, Miss Virginia Jussen, of Cincinnati, Ohio, one of Doctor Dryden's students. The specimen is quite well preserved, though somewhat distorted through crushing. Figures 1–3 show sketches of the brachial and pedicle valves. Comment upon its identity is hardly necessary, so clearcut is the example. The characteristics of the plications and their relative size and distribution are at once distinctive and serve to separate it from any contemporaneous *Spirifer*, and the surface details are unmistakable. There is some superficial resemblance to *Spirifer disjunctus* of the Chemung, but that brachiopod is unknown east of the Susquehanna Valley in Pennsylvania, because that valley marks the eastern limit of marine Chemung sedimentation in this latitude.

The specimen was collected from the coral reef already mentioned, which is finely exposed on Highway 90, about two miles north of Stroudsburg along the valley of Brodhead Creek. The bed has already been described and its fossils listed by the author (4). In discussing it, he tentatively correlated the reef with the Centerfield limestone member of the basal Ludlowville of New York. The reef is an important key bed, as it has been identified as far west as Perry County. Its most fossiliferous locality is that 2 miles north of Stroudsburg. A revision of the list already published for that locality to include *Spirifer divaricatus* follows:

Receptaculites? sp.

Streptelasma rectum Hall, *Zaphrentis prolifica* Billings, *Z. simplex* Hall, *Z.* sp., *Aulacophyllum* sp., *Craspidophyllum archiaci* (Billings), *Ceratopora jacksoni* Grabau, *Syringopora maclurei* Billings?, *Favosites hamiltoniae* Hall?, *F. clausus* Rominger, Corals, undet.

Crinoidea, columnals.

Hederella? sp., *Monticulipora* sp., *Fenestella biseriata* Hall?, *F. laevinodonta* Hall?, *F. parallela* Hall, *F.* sp., *Thamniscus* sp., Bryozoa, undet.

Stropheodonta demissa (Conrad), *Leptostrophia perplana* (Conrad), *Chonetes mucronatus* Hall, *Productella spinulicosta* Hall, *Dalmanella* sp., *Rhipidomella vanuxemi* Hall, *Camarotoechia* sp., *Tropidoleptus carinatus* (Conrad), *Atrypa reticularis* (Linné), *Elytha fimbriata* (Conrad), *Spirifer angustus* Hall, *S. mucronatus* (Conrad), *S. granulosus* (Conrad), *S. audaculus* (Conrad), *S. sculptilis* Hall, *S. divaricatus* Hall, *Vitulina pustulosa* Hall, *Athyris spiriferoides* (Eaton), Brachiopod, indet.

Aviculopecten sp., *Modiomorpha concentrica* (Conrad), *Glyptodesma erectum* (Conrad), *Actinopteria* sp.

Turbo, n. sp.

Dalmanites boothi (Green), *Phacops rana* (Green), *P.* sp.

Plantae, fragments.

FIGS. *1–3*—*Spirifer divaricatus* Hall, Monroe County, Pennsylvania; 1, pedicle valve; *2*, brachial valve; *3*, enlarged portion of surface.

The reporting of the species in itself may seem a trivial matter, considering its rarity in Pennsylvania and its rather long geologic range elsewhere. However, this single identification from Pennsylvania in contrast to the abundance in New York is interesting, and its occurrence in both states at the base of the Ludlowville serves as a final step in tying in the coral reef of Pennsylvania, whose value as a key bed we cited, with the Centerfield of New York. Also, by its discovery, the geographic distribution of this species is increased, and its extension southward in Hamilton time along the ancient coastal region of Appalachia is established as far as eastern

Pennsylvania. From its rarity, however, it is deduced that it probably will not be found farther south in post-Onondaga beds, and that the present discovery may mark its southern limit in Hamilton time in the eastern United States.

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A MISSISSIPPIAN GONIATITE FROM VIRGINIA

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ABSTRACT

Protocanites lyoni (Meek and Worthen) is described from the lower portion of the Price formation of southwestern Virginia. That species has been found previously in Indiana, Ohio, Missouri, and possibly Germany, and it has always been regarded as characteristic of the Lower Mississippian. However, the beds which yielded the Ohio and the Virginia representatives are now generally referred to the Osage group of the Middle Mississippian or Valmeyer series.

Recently Dr. Charles Butts sent me for study a single goniatite which he collected in 1926 in a shale pit one-half mile southwest of Richlands, Virginia. The specimen is not well preserved, but it is clearly referable to *Protocanites lyoni* (the type of *Protocanites* Schmidt), originally described by Meek and Worthen (1) from the Rockford limestone at Rockford, Indiana, where it is not particularly rare. Herrick (2) has since illustrated a representative of it from the upper portion of the Cuyahoga formation (the "Waverly freestone") at Granville, Ohio; in an unpublished manuscript on the Kinderhook cephalopods of Missouri I have described and illustrated an additional representative from the Chouteau limestone at Danville, Missouri; and Spiegelhalter (3) and Schmidt (4) have studied specimens from the basal Lower Carboniferous and uppermost Devonian of Germany which they believe to be very closely related or even conspecific with the American types —Schindewolf (5), however, has shown that all of these German specimens, with the possible exception of one from the Lower Carboniferous of the southern Schwartzwald, should be eliminated from the species. In all of these widely separated localities, except Ohio, this species occurs in beds which are clearly Lower Mississippian (Kinderhook or Lower Tournaisian) in age, but the Cuyahoga formation of Ohio, which Herrick (2), Weller (6), and J. P. Smith (7) believed to be Kinderhook, is now generally referred to the Osage group of the Middle Mississippian or Valmeyer series.

The specimen came from the lower portion of the Price formation, and the fossils found in that formation in the Richlands shale pit, more or less in association with the goniatite, have been identified by Doctor Butts as follows:

Fenestella herrickana Ulrich, *F. tenax* Ulrich, *Chonetes*? sp., *Productus duplicostatus* Winchell, *P. nebraskensis* Herrick [not Owen !], *P. rushvillensis* Herrick, *Centronella*? sp., *Cryptonella*? *inconstans* (Herrick), *Spiriferina depressa* Herrick, *Athyris* aff. *A. crassicardinalis* White, *Camarotoechia*? sp., *Camaro-*

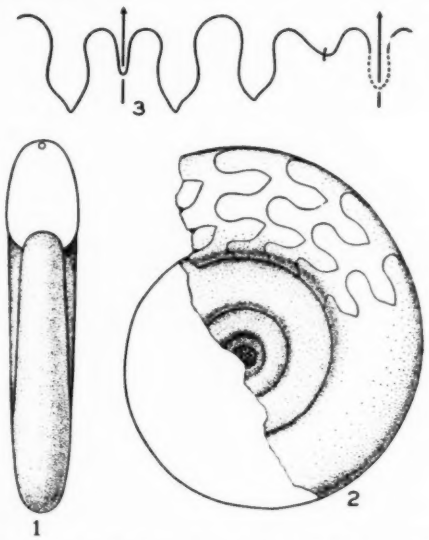
toechia 2 sp., *Dexiobia* or *Oracardia* sp., *Palaeoneilo marshallensis* (Winchell), *Palaeoneilo* cf. *P. marshallensis* (Winchell), *Goniodon ohioensis* Herrick, *Schizodus triangularis* (Herrick), *Streblopteria*? sp., *Allorisma consanguinatum* Herrick, *Cypricardella* cf. *C. bellistriata* (Conrad), *Cypricardinia*? sp., *Euphemus galericulatus* (Winchell), *Pleurotomaria stella* Winchell, *Plexrotomaria*? sp., *Straparollus*? sp., *Loxonema* cf. *L. yandellanum* Hall, *Orthoceras indianense* Hall, *Orthoceras*? sp.

Furthermore, Doctor Butts has written me that the marine Price corresponds with the Cuyahoga and thence with the New Providence and the Burlington. Several years ago I made a thorough study of the Kinderhook cephalopods of Missouri, and at that time was convinced that the Cuyahoga of Ohio is Kinderhook and not Osage in age. However, last year I (8) studied five goniatites from the Burlington formation, representing five distinct species of the genus *Münsteroceras*, and found them strikingly similar to forms that occur in the Kinderhook. Also the genus *Protocanites* occurs in Europe in beds that are in part the equivalent of the Osage. It may well be, therefore, that *Protocanites lyoni* occurs in both the Kinderhook and the Osage, but I believe we should not overlook the fact that the goniatites, taken by themselves, would indicate that the Cuyahoga of Ohio and at least the lower part of the Price of Virginia are Kinderhook in age. Furthermore, Moore (9) has recently placed the Cuyahoga (exclusive of the Black Hand) in the Kinderhook.

In view of the fact that no Mississippian goniatites have so far been described from Virginia, and since the specimen I am studying seems to be very significant, indicating either that *Protocanites lyoni* ranges up into the Osage or that the lower part of the Price is Kinderhook, I believe that the following illustrations and description of it are worth publishing.

PROTOCANITES LYONI (Meek and Worthen)

The specimen is preserved in a small block of fine-grained ferruginous brown sandstone, exceedingly fossiliferous, containing internal molds of many small brachiopods, gastropods, crinoid stems, and other fossils. Only an external mold of most of the goniatite is preserved, but at the adoral end of the specimen an internal mold of four (and a portion of a fifth) camerae is retained. One side of this internal mold shows the shape of the sutures quite clearly.



FIGS. *1–3*—*Protocanites lyoni* (Meek and Worthen). Ventral and lateral views, ×1, and diagrammatic representation of a suture, ×2, of a specimen from the Price formation near Richlands, Virginia. Figure *2* is in part a restoration, and figure *1* is entirely so.

Specimen represents only phragmacone; maximum diameter, measured across umbilicus, about 48 mm.; maximum height and width of conch about 14 mm. and 10 mm., respectively. Whorls compressed, flattened laterally, broadly rounded ventrally, impressed dorsally; maximum width of conch just ventrad of umbilical shoulders. Umbilicus large, open; umbilical shoulders rounded. Exterior of test smooth, apparently marked only by growth-lines, of which faint traces are discernible. Suture with rather small, V-shaped ventral lobe; on either side of it a rounded U-shaped first lateral saddle, a larger pointed asymmetrically tongue-shaped first lateral lobe, a larger rounded more or less

U-shaped second lateral saddle, a smaller pointed asymmetrically tongue-shaped second lateral lobe, a low asymmetrical rounded third lateral saddle, a shallow asymmetrical narrowly rounded lobe on the umbilical seam, and a rounded internal lateral saddle which extends to dorsal lobe. Precise shape of dorsal lobe cannot be ascertained from this specimen. Siphuncle small, apparently circular in cross section, ventral and marginal in position.

Protocanites lyoni is not closely similar to any other form known from America, but it resembles *P. supradevonicus* Schindewolf, of the uppermost Devonian ("*Gattendorfia*-Stufe") of Germany, in which the conch is marked by small but rather prominent transverse ribs and the ventral lobe of the sutures is relatively large and is not V-shaped. In Europe the genus *Protocanites* is known to occur in the Upper Devonian and in the Lower and the Middle Tournaisian, but in America it appears to be confined to the Tournaisian equivalents.

Hypotype.—U. S. Nat. Mus., 92,431.

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Discussion of age of Price formation, by Charles Butts.—The fossil associates of this example of *Protocanites lyoni* prove surely the Cuyahoga age of the beds in which it occurs. As to the question whether the Cuyahoga is Osage or Kinderhook, the following remarks apply:

The Kinderhook age of the Berea grit appears to be generally accepted. Girty recognized the Berea in the hills south of Corry, Pennsylvania, where the sandstone carries a species of *Paraphorhynchus*, so far as known a Kinderhook genus. Still farther east, near Warren, Warren County, Pennsylvania, *Paraphorhynchus* occurs at the top of a conglomeratic sandstone, the Knapp sandstone, which contains also a fossil formerly named by Hall *Rhynchospira scansa*. Really this is an *Eumetria* and I regard it as probably identical with *Eumetria altirostris* White, a fossil occurring in the Kinderhook of Iowa. Furthermore, a thin sandy limestone in the Knapp, at a locality on the Buffalo, Rochester, and Pittsburg Railroad between Lewis Run and Bingham, McKean County, Pennsylvania, some 10 to 15 miles southeast of Bradford Pennsylvania, has yielded a single specimen of the dorsal valve of a species of *Shumardella* closely resembling *S. missouriensis* (Shumard), another Kinderhook fossil. Caster reports finding specimens of *Chonopectus* in Pennsylvania and Ohio. This also is a Kinderhook fossil.

The Knapp, containing *Paraphorhynchus*, has been traced southward to Oil City, Pennsylvania, near which place it passes below drainage. In the hills above Oil City, and extending south into Armstrong County lies the Pocono, made up of a sandstone, the Shenango or Burgoon, at the top and a few hundred feet of fossiliferous shale, limestone, and sandstone below. All of these beds are continuous westward into the Cuyahoga of

Ohio. The fact that the Berea underlies the Cuyahoga of Ohio on its western outcrop need hardly be cited. Stratigraphically, therefore, the Kinderhook underlies the Cuyahoga.

As to the Osage age of the Cuyahoga the best evidence is perhaps afforded by the crinoids of the New Providence formation found in Buttonmould Knob, south of Louisville, Kentucky, described by Springer (The crinoid fauna of the Knobstone formation: U. S. Nat. Mus., Proc., vol. 41, pp. 175–208, 1911.). His conclusion was that the New Providence (Knobstone) of Buttonmould Knob is of Burlington age.

I have traced the New Providence formation from the Louisville region continuously to the Ohio River at Portsmouth, Ohio, where it connects with the Cuyahoga formation traced southward by Hyde through Ohio to Portsmouth (Stratigraphy of the Waverly formations of central and southern Ohio: Jour. Geol., vol. 23, pp. 655–682 and 757–779, 1915). Not far south of Portsmouth the Cuyahoga is underlain by the Berea sandstone in outcrop. Thus the post-Kinderhook age of the Cuyahoga and Price seems fully established.

QUANTITATIVE EXAMINATION OF MOLLUSCAN FOSSILS IN TWO SECTIONS OF PLEISTOCENE LOESS IN ILLINOIS

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ABSTRACT

Measured quantities of material taken at stated intervals in two sections of loess were examined to determine the sequence of species and the number of individuals present in each sample. One section, in Yarmouth loess in Cass County, Illinois, yielded fossils only in the upper foot; the other, in Wisconsin (post-Normal) loess in Bureau County, Illinois, showed increase in fossil content from base upward. It is suggested that at the time when the mollusks lived the climate was somewhat cooler than now, probably like that of southern Canada north of Illinois.

The vertical variation in the distribution of molluscan shells in loess deposits has been commented upon by several students of the Iowa loess fauna. Professor Shimek (1) writes:

> The vertical distribution of the shells in the loess is also very variable, suggesting that as the loess was forming, surface conditions and the surface fauna changed, usually more or less gradually.

He thus attributes the changes in the fauna entirely to changes in the environment. Commenting on these changes the present writer (2) recently made the following observation:

> A study of the vertical distribution of the shells in the loess of one exposure shows some variation in the character of the species represented, indicating changing conditions during the loess deposition, some of which may as well have been due to climatic as to edaphic conditions. As far as Illinois is concerned, not enough detailed data are available for the satisfactory answer to this question.

Published studies are rare that give account of vertical sections in loess from which material has been collected stratigraphically and in measured quantities, and the included species studied as to variation in character. Through the kindness of Dr. George E. Ekblaw, Geologist of the Illinois State Geological Survey, and of Dr. M. M. Leighton, chief of the Survey, collections were made from an exposure of Yarmouth loess and one of Wisconsin (post-Normal) loess, from the basal gravel to the top of the exposures. The fauna in one section suggests climatic change; in the other, no change.

With respect to living faunas, conditions in a given area may vary considerably within narrow limits. Many land mollusks live in colonies and many empty shells will therefore be found together; others may be washed into a hollow in the forest floor or may accumulate about the base of a tree trunk. This may not be strictly true, however, of all Recent faunas.

A study covering several miles of woodland territory in northern Minnesota showed remarkable uniformity of distribution of the small molluscan fauna in the debris of the forest floor. This distribution was both vertical and horizontal, empty shells being found several inches below the surface. The larger species are more widely scattered, and in the woodlands of Illinois are usually found in colonies. In the prairie fauna of Illinois, now best developed along railroads, the small species, especially the pupoids, are more uniformly distributed.

It is noteworthy that many of the loess faunas consist mostly of the smaller forms and that these are distributed rather uniformly throughout the loess matrix. The larger forms, the Polygyras, where present, are in scattered colonies. The loess faunas therefore do not differ in distribution materially from the Recent faunas found in Illinois.

The two sections reported in this paper are manifestly insufficient basis for an estimate of distribution of species in time or of changes of climate. They are, however, suggestive. It is believed that if many such vertical sections at one exposure were studied and the data from these compared with sections made in a similar manner at other localities, the information obtained might make possible definite conclusions concerning climatic variation during the long period of loess deposition. The question of climatic conditions during the Pleistocene period has been discussed by the writer in a previous paper (3) based upon about 350 exposures containing terrestrial molluscan fossils.

METHOD OF STUDY

In the field: A column of loess, from gravel base to top of exposure was marked, and measured portions removed in sacks, each sack numbered to show its place in the section. The samples ranged from 8 cubic inches to 20 cubic inches in one section, and were uniformly one cubic foot in the other. The distances between the samples differed according to the local circumstances.

In the laboratory: Each sample was carefully washed through a fine sieve to preserve all the small fossils. Of the larger samples, a cubic foot of material, small portions only were washed and the approximate distribution of fossils throughout the entire mass determined. The fossils were then classified according to species, and the number of individuals of each species counted. All material has been preserved in the Pleistocene collection of the Museum of Natural History of the University of Illinois.

THE SECTIONS

Section in Yarmouth Loess Planed by Illinoian Glacier

Location: NW. ¼ SE. ¼ sec. 27, T. 3 N., R. 2 E., along Wilson Creek, Beardstown Quadrangle, Cass County, Illinois.

Material: Loess, silt, soil, and gravel; 31 samples, collected consecutively from top to bottom. Samples 1 to 6 at 2-inch intervals (8 cubic inches each); samples 7 to 24 at 4-inch intervals (20 cubic inches each); samples 25 to 31 at 3-foot intervals (20 cubic inches each).

Top 2 inches, loess
.....8 species, 62 specimens, land shells
4 inches below surface, loess
.....6 species, 62 specimens, land shells
6 inches below surface, loess
.....5 species, 8 specimens, land shells
8 inches below surface, loess.....no fossils
10 inches below surface, loess.....no fossils
12 inches below surface, loess
.....1 species, 1 specimen, land shell
14 to 66 inches below surface, loess..no fossils
70 inches below surface, reddish and pinkish loess.....no fossils
74 inches below surface, heavy silt, washes slowly.....no fossils
78 inches below surface, heavy silt, washes slowly.....no fossils
82 inches below surface, sandy silt, blue, clayey.....no fossils
Black soil zone
3 feet below soil zone, sandy silt...no fossils
6 feet below soil zone, greenish silt...no fossils
9 feet below soil zone, yellow sandy silt
.....no fossils
12 feet below soil zone, yellow sandy silt
.....no fossils
15 feet below soil zone, gravel and greenish silt.....no fossils
18 feet below soil zone, second black soil zone
.....no fossils
21 feet below soil zone, greenish silt..no fossils
23 beet below soil zone, third black soil zone
.....no fossils
25 feet below soil zone, gravel

Interpretation of the section.—The basal gravel probably represents outwash from the

Kansan glacier. The silts represent wash and possibly some wind-action, and the soil horizons possibly originated in forests. The absence of fossils in the lower silt and soil zones is noteworthy and is probably to be accounted for by the normal chance distribution observed by naturalists in the faunas of the present time. Above the upper soil zone the material is blue, clayey sandy silt. No fossils were noted and the material suggests deposition in water. The overlying eight inches of material are true loess, but it is heavy and washes slowly. Above this zone the material is true loess, fine and compact, washing rapidly.

In the 82 inches of loess above the upper soil zone, fossils were not noted below the uppermost foot of the section, and are found in abundance only in the topmost six inches. From this section alone it might be inferred that conditions succeeding the time of the black soil zone were not suitable for molluscan life until approximately six feet of loess had been formed, but sections from other parts of this area might strongly modify this statement.

In the "12-inch" unit only one specimen of *Polygyra hirsuta*, a common land-snail of Recent and Pleistocene time was found. In the "6-inch" unit five species, represented by eight specimens, were found:

Polygyra hirsuta (Say).....1 specimen
Discus macclintocki (F. C. Baker).....3 specimens
Euconulus fulvus (Müller).....1 specimen
Strobilops labyrinthica (Say).....3 specimens
Succinea ovalis pleistocenica (F. C. Baker).....2 specimens

In the 4-inch unit six species represented by 20 specimens were found:

Polygyra hirsuta (Say).....5 specimens
Strobilops labyrinthica (Say).....6 specimens
Helicodiscus parallelus (Say).....1 specimen
Retinella electrina (Gould).....1 specimen
Succinea ovalis pleistocenica (F. C. Baker).....5 specimens
Succinea grosvenori gelida (F. C. Baker).....2 specimens

The "2-inch" layer contained eight species, represented by 62 specimens:

Polygyra hirsuta (Say).....1 specimen
Strobilops labyrinthica (Say)....40 specimens
Discus macclintocki (F. C. Baker).....1 specimen
Helicodiscus parallelus (Say).....5 specimens
Retinella electrina (Gould).....2 specimens
Cochlicopa lubrica (Muller).....1 specimen
Succinea ovalis pleistocenica (F. C. Baker).....10 specimens
Succinea grosvenori gelida (F. C. Baker).....2 specimens

It is to be noted that fossils are confined to the upper six inches of the loess and that none were found below 12 inches from the surface. It is to be noted also that the surface of this section had been planed by the Illinoian glacier and an unknown amount of material removed.

With the exception of *Discus macclintocki*, which has not been observed in the Recent fauna, all of the species are living in Illinois and the upper Mississippi Valley at the present time. The two varieties of *Succinea* are found in their typical form only in the Pleistocene. From the fauna represented, it might be assumed that the climate was similar to that of Illinois at the present time. The small pupoids abundant in other sections of loess are notably absent.

Section in Wisconsin (Post-Normal) Loess

Location: Center SW. ¼ sec. 34, T. 17 N., R. 8 E., 4 miles north and 1 mile east of Wyanet, Buda Quadrangle, Bureau County, Illinois.

Material: Exposure shows 6 feet of non-fossiliferous leached loess resting upon 5 feet of calcareous loess, resting in turn upon gravel. Four samples from the calcareous loess, approximately one cubic foot from each 15-inch interval.

First 15 inches of calcareous loess below top contains five species, 1188 specimens of land snails:

Succinea grosvenori gelida (F. C. Baker).....671 specimens
Columella alticola (Ingersoll)...307 specimens
Vertigo modesta Say..... 93 specimens
Pupilla muscorum (Linné).....109 specimens
Discus cronkhitei anthonyi (Pilsbry)..... 8 specimens

Second 15 inches below top contains four species, 769 specimens of land snails:

Succinea grosvenori gelida (F. C. Baker).....497 specimens
Columella alticola (Ingersoll)... 97 specimens
Vertigo modesta Say.....173 specimens
Pupilla muscorum (Linné).... 2 specimens

Third 15 inches below top contains three species, 265 specimens of land snails:

Succinea grosvenori gelida (F. C. Baker).... .....246 specimens
Columella alticola (Ingersoll)... 12 specimens
Vertigo modesta Say..... 7 specimens

Fourth 15 inches below top, resting on gravel, contains one species, 16 specimens of land snails:

Succinea grosvenori gelida (F. C. Baker).... ..... 16 specimens

A cubic foot of loess from the top of another section contains five species, 1498 specimens of land snails:

Succinea grosvenori gelida (F. C. Baker)..... .....846 specimens
Columella alticola (Ingersoll)...390 specimens
Vertigo modesta Say.....242 specimens
Pupilla muscorum (Linné).... 19 specimens
Discus cronkhitei anthonyi (Pilsbry)..... ..... 1 specimen

Interpretation of the section.—The gravel represents outwash from the Normal moraine. The loess evidently began forming immediately after the recession of the ice front, for it lies directly on the gravel. The lower 15 inches of loess contain little evidence of life, only one species of *Succinea* represented by 16 specimens occurring in the sample. The lower part of this sample was barren of fossils, the snails appearing in the upper part of the sample. This would indicate, probably, that conditions were not favorable for mollusks when the loess was first laid down. It is also probable that grasslands or prairies appeared before forests and the *Succinea* might have inhabited such a region, as the Recent species *S. avara* and *grosvenori* do today in parts of Illinois. In the third 15 inches three species occur in considerable number, indicating that forest conditions had developed to some degree, though the few specimens of *Columella* and *Vertigo* and the large number of *Succinea* suggest that the environment may have been open woodlands. The second 15 inches shows an increase in number of species and a large increase in number of individuals, indicating a habitat of well-developed forest. In the upper 15 inches this condition is even more distinct, five species being represented by over a thousand individuals.

Taking the section as a whole, the calcareous loess shows a gradual upward increase in the molluscan population, both as to species and individuals. The presence of a small number of specimens of the little *Succinea* in the loess immediately overlying the gravel suggests that the mollusks took possession of the territory very early in the accumulation of the loess deposit. The increase in species and individuals in the middle and upper part of the calcareous loess suggests an environment increasingly suitable for this type of life, which would include abundant vegetation for shelter and food. It is to be understood, of course, that other sections from this area might modify this interpretation to some degree.

Another feature observed in this section is that in the upper 30 inches the snail shells are rather evenly scattered throughout the samples. As far as could be observed by a careful examination of the material in each sieve-washing, there was no "bunching" of specimens, such as is found in present-day forests where a number of shells of various species are washed into depressions by rain, or where the species occur in colonies.

A consideration of the species found in the calcareous loess is highly suggestive. Of the five species represented, three are foreign to Illinois and the adjacent parts of the Mississippi Valley. These are *Columella alticola*, distributed at present from Alberta south to Arizona in the Rocky Mountain region, and in British Columbia, mostly at high altitudes. In Colorado it is an alpine form. *Vertigo modesta*, known from Labrador westward to Vancouver Island and locally in Maine, Vermont, and Connecticut. *Pupilla muscorum*, a common species in the north and in the Rocky Mountain region as far south as New Mexico. At lower elevations in the United States it is known from Maine, Massachusetts, New York, New Jersey, and the northern tier of states. It is not listed from Ohio, Indiana, or Illinois. It is rare in Michigan and apparently absent from Wisconsin and Minnesota. South Dakota and Kansas appear to be the locations nearest to the Pleistocene regions of Illinois.

It will be observed, therefore, that the fauna of the post-Normal loess is decidedly western and northern, in terms of the living fauna, and is quite different from the molluscan fauna inhabiting Illinois and adjacent

states at the present time. It resembles more nearly that now found in Colorado and adjacent regions. Possibly there was an eastward migration of the fauna following the retreat of the Wisconsin ice; possibly some or all of the species inhabited Illinois before the oncoming of the Wisconsin glacier, as one would expect a cold temperate climate under such circumstances. That conditions were favorable for the development of a rich fauna is attested by the great number of individuals in the samples examined.

Another feature observed in this section is that all species are small mollusks, the pupoids being almost minute. Not a large snail, such as characterizes the same region today, is included. The same condition has been observed in the Recent land-snail faunas of northern Minnesota and Wisconsin. Whether this difference between the Recent and the Pleistocene faunas is due to climatic or environmental changes is not at present definitely known, although an isothermal shift is suggested by the past and present distribution of the faunas. It is believed by the writer that extensive studies of loess and other Pleistocene deposits made as suggested in this paper would go a long way toward settling this question.

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3. *Idem*, p. 272.

Note: The manuscript of this paper was received by the editor of the Journal May 1, 1935.

RADIOLARIA IN THE ARKANSAS NOVACULITE, CABALLOS NOVACULITE, AND BIGFORK CHERT

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Increasing interest in the stratigraphy of the Ouachita Mountain region has made it seem appropriate to give preliminary notice of a discovery that throws new light on the origin of the Arkansas novaculite, Caballos novaculite, and the Bigfork chert.

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A few years ago I found that the use of dark-field illumination was so successful in exhibiting obscure structures of Foraminifera in certain thin sections that I determined to renew efforts to find fossil microörganisms in the Arkansas novaculite. Late in 1932, Mr. H. D. Miser supplied me with a number of collections of banded and concretionary novaculite and chert from the Ouachita region and also from the West Texas region. Large thin sections were cut from the specimens across the bedding to cover the stratigraphic range that each specimen represented.

Upon examination, all of the collections exhibited numerous Radiolaria, some being well preserved. The results far exceeded my expectations, as a number of specimens are not especially difficult to see and are generally most easy to study in bright-field illumination.

In anticipation of a more thorough and comprehensive study of the silica-fixing faunas and lithology of these formations, the geologists at work in that region may find use for the data and conclusions given below.

ARKANSAS NOVACULITE

Collection Q9, 3/27/33, Henbest; Arkansas novaculite (upper), banded, black flint; gap of Walnut Creek, 1 mile west of Albion, Oklahoma; collector, H. D. Miser.

Collection Q8, 3/27/33, Henbest; Arkansas novaculite; Potato Hills, southwest of Talihina, Oklahoma; collector, H. D. Miser.

Collection includes a concretion and banded novaculite.

Both of these collections yielded great numbers of Radiolaria, but the concretion contained the best preserved specimens. The concretion stained deeply with methylene blue, which was a material aid in resolving the structures.

The well-preserved species in these collections have a thinner outer capsule than the dominant Caballos novaculite species. A few exhibit external spines and one specimen an internal capsule with massive radii. In the clear, varved-novaculite specimens, the radiolarian skeletons appear like balls of linty cotton and resemble a form which I have etched out of phosphatic nodules collected by Mr. C. B. Read from the New Albany shale of Kentucky.

CABALLOS NOVACULITE

Collection R4, 3/27/33, Henbest; Caballos novaculite; Marathon, Texas; collector, H. D. Miser.

Radiolarian skeletons are very numerous in this collection but belong to only a few species. The absence of a varied assemblage may, perhaps, be the result of poor preservation of some forms or the fortuitous striking of a non-representative locality, or it may mean, as it appears, an exclusive dominance of a few species. The skeletons are symmetrical, radially spinose, and have an outer and a single internal capsule. The outer capsule appears to have a honeycomb structure. They belong therefore to the Spumellaria.

Along with the Radiolaria, and concentrated in certain varves or parts of varves, are a large number of minute, very dark brown organic remains which I have so far been unable to connect definitely with known organisms. I am attempting to isolate these objects by means of hydrofluoric acid but have only remote hopes that these fossils are insoluble.

As in collections Q8 and Q9, Arkansas novaculite, the skeletons are in part concentrated in association with the varves, and a large number show varying degrees of flattening, but a few of the better preserved individuals appear to have a distribution that is not so closely associated with the varves, a condition that turned out to be more apparent than real. The larger part of the organic detritus is zoned, however, and is probably the chief cause for the varved appearance of the rock from a macroscopic viewpoint.

Radiolaria were first discovered in the Caballos novaculite by Baker and Bowman (3, 4), who figured some specimens.

BIGFORK CHERT

Collection R3, 3/27/33, Henbest; Bigfork chert (varved); Quarry at Stringtown, Atoka quadrangle, Oklahoma; Collector, H. D. Miser.

The specimens at hand are varved and contain a variety of microörganisms, many of which are not identifiable in thin section. Of particular significance here is the presence of a large number of isolated sponge spicules, monaxons, and polyaxons of different types. It will require thicker sections and a more extended study to determine the exact forms of these spicules.

Associated with the spicules are numerous hollow, spherical bodies having the size and general appearance of spumellarians, but I am unable to resolve the structures with adequate clearness to say definitely that they are radiolarians. A few showed vague traces of external spines and one a vague trace of an internal capsule and portions of supporting radii, but these were all too indefinite for a positive identification.

ORIGIN OF THE NOVACULITE AND CHERT

This presence of Radiolaria has obvious consequences on the theory of the origin of these cherts and novaculites. The Arkansas novaculite problem has been especially enigmatic, as organic remains have previously been supposed to be extremely rare. The discovery of numerous conodonts by Miser and Purdue (5, p. 54) and further collection and discoveries by Cooper (6, 7) indicate that the novaculite is anything but barren, but these discoveries have had little or no connection with the problem of the silica, except to indicate that the beds are marine.

Griswold (1), Honess (2), and Miser and Purdue (5, pp. 55–59) have presented com-

prehensive reviews of previous theories, to which the reader is referred, in addition to proposing their own theories and offering new evidence. By analogy with the Caballos novaculite, Baker (3, 4) has supposed that the Arkansas novaculite is radiolarian in origin.

It is pertinent here to note that the supposed absence of silica-fixing organisms forced previous attempts at explanation, except that of Baker and Bowman (4, p. 101), to invoke inorganic origins. The discovery of silica-fixing organisms in the Arkansas novaculite gives the investigation a final turn which should result in a more satisfactory and comprehensive explanation of these astonishing deposits. It appears to the writer that some if not all of the theories of origin contain ideas and much factual material which demand inclusion in a generally acceptable theory. It is not yet permissible to conclude that all of the silica in these deposits was precipitated directly and indirectly by organic means, because the specimens at hand may not be generally representative, but it would not be surprising if such origin proved to be true.

In determining the causes and origin of the Arkansas novaculite, the character of the physical background of diastrophism, marine invasion, and the extensive supply of volcanic ash as described by Honess cannot be ignored nor merely be taken for granted. Over-emphasis of the biological aspect of the phenomenally extensive and long-continued expansion of silica-fixing organisms would present a stark, isolated picture without a description of the conditioning geologic factors. These things are particularly appropriate as the discovery of Radiolaria accounts definitely for only a portion of the silica. The rest remains to be explained regardless of the probability that most of it is directly or at least indirectly organic in origin and is accordingly syngenetic. Cavities of the radiolarians are generally filled with clean, clear silica.

The following conditions are suggestive:

(1) Generally the novaculite and chert formations are evenly bedded, and individual beds are persistent.

(2) The specimens at hand contain no drusy geodes nor agate concretions and bands.

(3) In certain parts of the sections the skeletal material of the radiolarians occupies a fair percentage, 2 to 25(+?) per cent, of the total mass. Generally, the average quantity of definitely identifiable skeletal material would appear to be from 0.5 to 5 per cent.

These conditions certainly indicate that the beds represented contained some silica originally and suggest, as Miser and Purdue (5, p. 57) have urged in another connection, an absence of any extensive surficial replacement of original limestone beds.

Radiolarian material from the Arkansas novaculite in Arkansas and Oklahoma is being collected and prepared for a more detailed study.

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PRAVOGNATHUS, A NEW NAME FOR *HETEROGNATHUS* STAUFFER (NOT GIRARD)

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In the October, 1935, number of the Journal of Paleontology (vol. 9, no. 7, pp. 606, 607, pl. 72), the writer described a genus of conodonts to which the name *Heterognathus* was applied. Paul H. Ochser of the United States National Museum, in a letter dated November 22, 1935, has called to my attention the fact that this name is preoccupied. Mr. Ochser writes:

I note that this name has been used before in Zoology as follows:

Heterognathus C. F. GIRARD, *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 7, p. 198, 1854. Pisces.

Heterognathus L. SCHMARDA, *Neue wirbellose Thiere*, etc., vol. 1, pp. xv, 48, 51, 1859. Vermes.

Heterognathus R. L. KING, *Ent. Soc. New South Wales, Trans.*, vol. 1, fasc. 2, pp. 91, 96, 1864. Coleoptera.

Heterognathus (subg. to *Hister*) C. REY, *Échange*, vol. 4, no. 47, p. 4, 1888. Coleoptera.

The generic name *Heterognathus*, as applied to conodonts, should be discontinued, and in its place the author wishes to suggest that *Pravognathus* be substituted. The three species affected, therefore, become *Pravognathus brevis*, *Pravognathus idoneus* and *Pravognathus simplex*.

ANNOUNCEMENT OF FIRST UNIT OF ILLUSTRATED CARD CATALOG OF DEVONIAN FOSSILS

The Paleontological Society's committee in charge of preparation of the *Illustrated Card Catalog of North American Devonian Fossils* announces that the first unit, no. 7*B*, the Ammonoidea, by Professor A. K. Miller, will be issued within a few weeks by the Wagner Free Institute of Science.

Types of all species of North American Devonian ammonoids have been studied in the effort to make this unit as useful to paleontologists as it can be made. Many new figures of type specimens are included, and it is believed that these cards will be indispensable not only to those especially interested in the Devonian but to all students of North American ammonoids. The committee stresses the fact that the edition will be limited and that orders should be sent in promptly.

It is requested that all paleontologists, institutions, and libraries which desire copies of this unit and have not already sent in their orders mail orders at once to Carl Boyer, Wagner Free Institute of Science, Montgomery Avenue and 17th Street, Philadelphia, Pennsylvania.

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